Chapter 2
Higher Education in Science and Engineering

Contents

Highlights

Worldwide Increase in S&E Educational Capabilities

- **From the mid-1980s to the mid-1990s, the number of first university degrees in higher education in science and engineering (S&E) increased rapidly in Asia and Europe, and slowly in North America.** During this period, first university degrees in S&E grew at an average annual rate of 4.8 percent among 16 European countries, at 4.1 percent among 6 Asian countries, and at 1.3 percent among North American countries.

- **The increase in S&E degree production in Asia is driven by expanding access to higher education for large or growing populations.** Developing countries such as India and China have large populations in their college-age cohorts and increasing participation rates in postsecondary education. The increase in S&E degree production in Europe is driven by expanding access to higher education in the face of a declining student population.

- **A higher percentage of the college-age population in selected Asian countries than in Europe or North America earns university degrees in the natural sciences and engineering (NS&E)**. In Japan, Singapore, South Korea, and Taiwan, between 6 and 7 percent of 24-year-olds earn NS&E degrees, compared to between 4 and 5 percent of 24-year-olds in Western Europe and North America.

- **In Europe, Asia, and North America, women have been particularly successful in earning degrees in the natural and social sciences.** By 1995, women earned close to half of the natural science degrees in higher education institutions in several countries, including the United Kingdom, Italy, the United States, and South Korea. Women in the three regions have also earned the majority of first university degrees in the social sciences, but are considerably less likely to earn degrees in engineering.

Characteristics of U.S. Higher Education Institutions

- **The United States has a large and diversified set of institutions of higher education that provides a college or university education to over one-third of the U.S. college-age population.** The country has one of the most open education systems in the world. Other countries are also broadening educational access and expanding their graduate programs, particularly in S&E fields.

- **After several decades of continual and rapid expansion of higher education in the United States, enrollment fell for the first time in 1993; it has continued to decline each year since.** This decline is partially based on demographics: the U.S. college-age population declined from 22 million in 1980 to 17 million in 1995. The decline in the college-age population was offset for over a decade by expanded access to higher education for all subpopulations, particularly women and minorities, and enrollment by larger numbers of older students. By 1993, however, overall enrollment began to decline.

Undergraduate S&E Students and Degrees in the United States

- **The trend of increasing enrollment of underrepresented minority students in undergraduate programs has persisted for over a decade and accelerated in the 1990s.** Black enrollment increased 3.6 percent annually in the 1990s, reaching 1.3 million in 1995. Hispanic enrollment in higher education increased at an even faster rate during this period (7.1 percent annually).

- **In 1995, at the community college level, over half (57.8 percent) of the enrollment in mathematics classes was for remedial level courses.** In 1970, remedial courses in community colleges accounted for about a third of all mathematics courses.

- **The percentage of freshmen in four-year institutions reporting a need for remedial work in mathematics and science has remained high, particularly for women and minorities.** In 1995, of those freshmen planning to major in science or engineering, over 16 percent of the males and over 26 percent of the females thought they would need remedial work in mathematics. Among freshman students from underrepresented minority groups planning to major in science or engineering, over 38 percent reported that they would need remedial work in math.

- **The number of earned bachelor's degrees in S&E from U.S. institutions has been increasing for over a decade, but trends differ by field.** The number of natural science degrees increased 7.7 percent annually from 1990 to 1995, with stronger than average growth in the biological and environmental sciences, but only modest (2 percent) growth in the physical sciences. Attraction to the computer sciences dropped precipitously from 1986 to 1991, followed by slight decreases to 1995. The number of social science degrees awarded, after record growth between 1986 and 1992 (averaging 6 percent annually), has remained stable for the last four years. Engineering degrees, whose numbers also peaked in 1986, declined until 1991 and then stabilized.

- **In 1995, for the country as a whole, over 5 percent of the college-age population had completed a bachelor's degree in an NS&E field.** But in that same year, only about 2 percent of black and Hispanic youth earned a bachelor's degree in an NS&E field. Asian Americans, representing only 4 percent of the U.S. population, have considerably higher than average participation rates: over 12 percent earned an NS&E degree. Low participation rates for blacks and Hispanics changed little throughout the 1980s, although they improved somewhat in the 1990s.

Graduate S&E Students and Degrees in the United States

- ♦ **Enrollment in U.S. graduate S&E programs grew for almost 20 years, reached a peak of almost 440,000 students in 1993, and then began to shrink.** The decline in enrollment has averaged 1 percent annually. Fewer students enrolling in engineering, mathematics, and the computer sciences account for most of this decline.
- ♦ **While women continued a decade-long trend of increased enrollment in graduate S&E programs in 1993, enrollment figures for U.S. white males began a downward trend.** In 1977, women represented only one-quarter of S&E graduate enrollment; by 1995, they accounted for 38 percent of enrollment.
- ♦ **Progress for underrepresented minorities in S&E graduate enrollment has been very modest.** In 1975, they accounted for 3.7 percent of S&E graduate enrollment; by 1995, they accounted for 5.0 percent.
- ♦ **In 1992, foreign graduate students reversed their decade-long trend of increased S&E enrollment in U.S. institutions.** They decreased their enrollment each year since then. From 1983 to 1992, the number of foreign graduate students increased over 5 percent annually. From 1992 to 1995, their numbers decreased more than 3 percent annually.
- ♦ **The number of S&E degrees awarded in the United States at the master's level increased throughout the 1980s, with even stronger growth in the 1990s.** The recent growth is mainly accounted for by rising numbers of earned degrees in the social sciences and engineering, with relatively stable numbers in the natural sciences, mathematics, and computer sciences.
- ♦ **The proportion of U.S. master's degrees earned by females increased considerably in the last two decades—not only in the natural sciences, but in engineering as well.** In 1975, females earned 21.1 percent of the natural science degrees at the master's level and 2.5 percent of the engineering degrees. By 1995, females accounted for 41.0 percent of natural science degrees and 16.2 percent of engineering degrees.
- ♦ **Asian Americans earned an increasing number of S&E master's degrees, while the number of such degrees awarded to underrepresented minorities grew only slightly.** The number of S&E master's degrees awarded to Asian Americans grew especially in engineering, mathematics, and the computer sciences. The number of S&E master's degrees obtained by blacks grew modestly in most fields, although there was strong growth in the social sciences. Hispanics also earned a modestly increasing number of degrees in the social sciences, as well as in engineering.
- ♦ **The number of doctoral degrees in engineering, mathematics, and the computer sciences nearly doubled from 1985 to 1995.** Natural science fields—particularly the biological sciences—contributed to the rising number of degrees, with a 30 percent increase.
- ♦ **Women accounted for an increasing proportion of S&E doctoral degrees, while underrepresented minorities showed only a slight increase.** By 1995, females earned almost half of the doctoral degrees in the social sciences, 38 percent in the biological sciences, and almost 12 percent in engineering. Underrepresented minorities received less than 5 percent of all S&E doctorates awarded in 1995, up slightly from 3 percent in 1977.
- ♦ **In the past decade, foreign students have accounted for the large growth in S&E doctoral awards in U.S. universities.** The number of foreign doctoral recipients in U.S. universities doubled in S&E fields from over 5,000 in 1986 to over 10,000 in 1995—an 8.2 percent average annual increase. In contrast, the rate of increase in doctoral degrees to U.S. citizens averaged only 1.9 percent annually.
- ♦ **The proportion of foreign doctoral recipients planning to remain in the United States has increased: for the 1992-96 period, over 68 percent planned to locate in the United States, and nearly 44 percent had firm offers to do so.** Stay rates differ considerably by place of origin. In 1996, 57 percent of the U.S. S&E doctoral recipients from China and 59 percent of those from India choose to accept employment in the United States. In contrast, only a small percentage of 1996 doctoral recipients from South Korea and Taiwan (24 and 28 percent, respectively) accepted employment offers in the United States.
- ♦ **From 1990 to 1994, U.S. universities provided slightly more than half of their postdoctoral appointments to non-U.S. citizens.** However, like the recent decline of foreign graduate enrollments in S&E in U.S. universities, there has been a slightly smaller proportion of foreign postdoctoral appointments and a slightly increasing number of appointments to U.S. citizens, particularly in the sciences. Foreign postdoctoral recipients still receive the majority of such research positions within U.S. universities in engineering.
- ♦ **One indicator of mobility of S&E personnel in the world is the proportion of foreign-born faculty in U.S. higher education.** In 1993, foreign-born faculty in U.S. higher education accounted for 37 percent of the engineering professors and 27 percent of the mathematics and computer science teachers. These faculty are mainly from Asia and Europe, with the largest numbers coming from India, China, the United Kingdom, Taiwan, Canada, and South Korea.

International Comparisons of S&E Training

- **Europe leads North America and Asia in S&E doctoral degree production.** In 1995, doctoral degrees awarded in S&E fields by Western and Eastern European institutions totaled 45,647—about 60 percent higher than the North American level and almost three times as many as the number recorded for Asian countries.
- **While graduate S&E programs are expanding rapidly in Asia, women have not yet entered those programs in large numbers.** Women still earn only a small fraction of the doctoral S&E degrees issued in Asia. In 1995, women in South Korea and Taiwan earned only 7 and 9 percent, respectively, of total S&E degrees at the doctoral level.

Introduction

Chapter Overview

Scientific discoveries, technological innovation, and the information revolution had a tremendous influence on U.S. society and the global economy in the late 20th century. These forces will have still greater roles in shaping the emerging knowledge society that will mature worldwide in the 21st century. The U.S. higher education system has facilitated this knowledge explosion and contributed, directly and indirectly, to the worldwide diffusion of science and engineering (S&E) knowledge. Consequently, encouragement of S&E education is a key element of the economic growth strategies of many countries around the world.

This chapter on higher education in S&E discusses trends that demonstrate the increasing globalization of S&E capabilities. At the undergraduate level, the globalization of science and technology has domestic implications for further openness in access to higher education in S&E fields for women and minorities, who will comprise the majority of the labor force in the 21st century. The increasing global capabilities for graduate S&E education have implications for the large international component of U.S. graduate S&E programs. This chapter includes indicators of the increase in capabilities for S&E education at the bachelor's and doctoral levels in three world regions: Asia, Europe, and North America. It also includes domestic indicators of current achievement in earning S&E degrees, both at the national level and for women and minorities.

Chapter Organization

This chapter begins and ends with international comparisons that put U.S. higher education indicators in a broader context. The comparisons at the chapter beginning are at the bachelor's level (referred to internationally as "first university degrees"), while those at the end are at the doctoral level. The initial international indicators relate to the number of S&E degrees: the growth rate over time of first university degrees, the proportion of S&E degrees produced among regions, participation rates of college-age cohorts in S&E degrees, differences in participation rates by sex, and the ratio of S&E degrees to total first university degrees by country.

The main body of the chapter focuses on U.S. higher education in science and engineering, including institutions, enrollment, and degrees at all levels. To a greater extent than is possible with the international indicators, domestic data illustrate trends in disaggregated fields, show coursetaking behavior at the undergraduate level, and note achievement by women and minorities. The following domestic indicators are disaggregated by race and sex: trends in enrollments, choice of S&E majors, need for remedial work in mathematics and science, participation rates in S&E degrees, and earned degrees at all levels.

Changes in the contributions of international students and faculty are explored in indicators on foreign doctoral students and stay rates in the United States of foreign doctoral recipients, the growth and change of postdoctoral appointments, foreign faculty in U.S. higher education, and reverse flows of U.S.-trained scientists and engineers to Asia.

The final chapter sections present science and technology indicators relating to international mobility. These include international comparisons of foreign student enrollment and comparison of doctoral S&E degree production in three world regions.

Note that trends are presented in terms of both S&E and the natural sciences and engineering (NS&E) throughout this chapter. These designate different aggregations of fields. S&E is the more inclusive term, including all fields; NS&E excludes social and behavioral sciences.[1] Both aggregations are included because trends differ among S&E and NS&E, particularly for women and minority groups (e.g., they are relatively better represented in the social and behavioral sciences). In addition, to make international comparisons more comparable in scope, NS&E is frequently used.

Worldwide Increase in S&E Educational Capabilities

In each country, a number of factors drive student participation in science and engineering. Among these are demographics (the number of college-age students), organizational aspects of the university system (how open—accessible—the system is), how the secondary education system dovetails into higher education, as well as the incentives for studying and staying in S&E as opposed to entering directly into the workforce. These factors combine in different ways in each country to influence the number of S&E students.

[1]The natural sciences comprise the physical, chemical, biological, agricultural, earth, atmospheric, and oceanographic sciences, as well as mathematics and the computer sciences.

First University Degrees[2]

From the mid-1980s to the late 1990s, the number of first university degrees in science and engineering increased rapidly in Asia and Europe and slowly in North America. In this period, first university degrees in S&E grew at an average annual rate of 4.8 percent among 16 European countries, at 4.1 percent among 6 Asian countries, and at 1.3 percent among North American countries.[3] When considering only NS&E degrees, the North American degrees declined at an average annual rate of just under 1 percent (NSF 1993 and NSF 1996a), while the European and Asian degrees increased over 4 percent.

In 1995, more than 2.1 million students in these three regions earned a first university degree in science or engineering, up from 1.6 million in 1992.[4] (See "Degree Data Available for Asia, Europe, and North America.") These 2.1 million degrees were evenly divided among the major fields: approximately 765,000 were earned in the natural sciences, 643,000 in the social sciences, and 739,000 in engineering. (See text table 2-1.)

By 1995, within the Asian region, the number of first university degrees in the natural sciences rose to over 300,000—almost as many as the number of such degrees earned in the European region, and about twice the number earned in the North American region. Within engineering, selected Asian countries produced over 343,000 degrees, 21 percent higher than the number of such degrees in Europe (including Russia), and more than three times the number earned in the North American region. (See figure 2-1, text table 2-1, and appendix table 2-1.)

Degree Data Available for Asia, Europe, and North America

Data availability differs among the countries of these three regions. Trend data on degrees earned in broad S&E fields have been developed for 6 Asian economies—China, India, Japan, Singapore, South Korea, and Taiwan; 16 Western European countries—Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom; and 3 North American countries—Canada, Mexico, and the United States. (See NSF 1993 and NSF 1996a.) Recent degree data covering one year only (1993 or 1994), for selected Central and Eastern European countries and Russia, were obtained from the Organisation for Economic Co-operation and Development (1996). In addition, more of Asia's developing countries—including Indonesia, Malaysia, and Thailand—have begun collecting and reporting their national education statistics to UNESCO's annual survey, providing a more complete picture of the Asian region.

Asia

Trend data from selected Asian countries show that for China, India, Japan, South Korea, Singapore, and Taiwan, the number of first university degrees in science and engineering fields increased greatly. Between 1975 and 1995, the total

[2]Data in this section are taken primarily from the National Science Foundation, Science Resources Studies Division, Global Database on Human Resources for Science.

[3]A first university degree refers to completion of an undergraduate postsecondary degree program. These degrees are classified as level 6 in the International Standard Classification of Education, although individual countries use different names for the first terminal degree: e.g., *laureata* in Italy, *diplome* in Germany, *maitrise* in France, and bachelor's degree in Asian countries and the United States.

[4]Data were available from fewer countries for the 1992 regional totals. The 1995 European data include some Eastern European countries as well as Russia. (See appendix table 2-1.) See NSB (1996), appendix table 2-1, for countries included in 1992 regional totals.

Text table 2-1.
First university degrees in S&E, by region: 1995 or most recent year

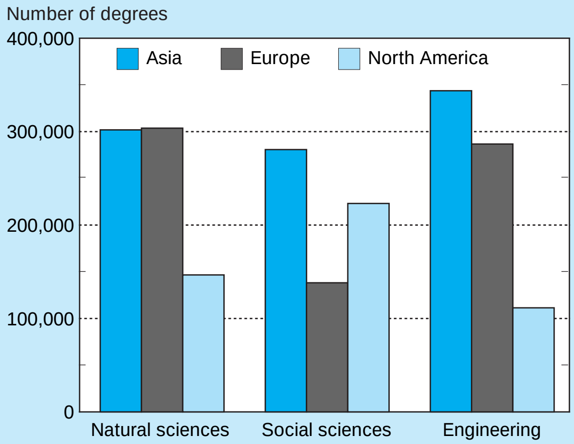
Field	Three-region total	Asia	Europe	North America
First university degrees, all fields	5,208,205	2,043,677	1,713,423	1,451,105
Science & engineering	2,146,648	926,426	732,263	487,959
Natural sciences	764,820	301,877	309,837	153,106
Social sciences	642,777	280,775	138,896	223,106
Engineering	739,051	343,774	283,530	111,747

NOTES: The requirements for first university degrees in S&E fields are not comparable across or even within the countries included in these three regions, particularly for European universities. For example, Germany includes both university degrees (with an average duration of 7 years) and *Fachhochschulen* degrees (polytechnics of 4.5 years' average duration) as first university degrees (level 6 in UNESCO classification). Work has been under way for several years at UNESCO, EUROSTAT, and the U.S. Department of Education to refine the levels of higher education for better comparability across countries. See, for example, U.S. Department of Education and National Science Foundation, *Mapping the World of Education: The Comparative Database System (CDS)* (Washington, DC: 1994). A new UNESCO survey will be designed and implemented by the end of this decade. See appendix table 2-1 for countries included in each region.

See appendix table 2-1.

Science & Engineering Indicators – 1998

Figure 2-1.
First university degrees in S&E, by world region: 1995 or most recent year



See appendix table 2-1. *Science & Engineering Indicators – 1998*

number of degrees in the natural sciences earned by students from these countries nearly doubled, while those in engineering more than tripled. (See NSF 1993 and appendix table 2-2.) In the last decade, the average annual growth rate in earned NS&E degrees in Asia was 4.2 percent. In contrast, in the North American region, the number of NS&E degrees declined at an average annual rate of 0.9 percent from 1986 to 1994. (See "Undergraduate S&E Students and Degrees in the United States" for further information on U.S. degree trends.)

The biggest increase in NS&E degrees in the Asian region came as a result of China reopening its universities and expanding its institutions of higher education in the 1980s. (See "Growth in Institutions of Higher Education in Asia.") From 1985 to 1995, earned degrees in the natural sciences rose from 28,000 to over 54,000; engineering degrees rose from 73,000 to almost 150,000. China has a strong commitment to higher education in the natural sciences (stressing the applied side of chemistry, physics, and biology); in 1995 it produced more than twice as many bachelor's degrees in these fields as did Japan. (See appendix table 2-2.)

China has the largest number of NS&E first university degree recipients at 203,238, followed by India at 176,036, and Japan at 127,971. However, with the large populations of China and India, the number of earned degrees represents a relatively small proportion of the college-age cohort. (See "Increasing Participation Rates in NS&E Degrees" later in this chapter and appendix table 2-1.)

China's rapid expansion of S&E degrees is partly explained by demography (its 20- to 24-year-old population equals 100 million) and partly by a national policy to extend higher education—particularly in science and engineering—in support of national economic development.

Europe

The increase in the number of S&E degrees awarded by higher education institutions in European countries is also noteworthy. (See "Growth in Institutions of Higher Education in Europe.") From 1975 to 1995, the Western European countries[5] collectively more than doubled their annual production of first university degrees in S&E. The number of natural science degrees increased from approximately 56,000 in 1975 to more than 150,000 in 1995. The number of social science degrees increased from approximately 50,000 in 1975 to over 80,000 in 1995. And the number of engineering degrees rose from 51,000 in 1975 to more than 137,000 in 1995. (See NSF 1996a and appendix table 2-1.)

The European expansion of higher education in science and engineering, and heavy investments in research and development (R&D), underpin a broader effort to maintain and enhance Europe's economic vitality through the European Union (EU). The EU is attempting to integrate the S&E research community and make the region's high concentration of science resources even more productive in order to increase competitiveness at the European and global levels (NSF 1996a).

Germany, France, and the United Kingdom account for most of this expansion of higher education; students from these three countries earned more than 60 percent of the first university degrees awarded in NS&E in Europe. The United Kingdom democratized its access to higher education through curricular reform of upper secondary education, providing the academic background for more students to continue in school past 16 years of age, with increased options to study science and subsequently enter the university. These reforms resulted in a significant increase in the number of NS&E degrees earned. Further, the number of U.K. degrees sharply increased in 1992 due to the reclassification of colleges and polytechnics as universities. In addition to a gradual expansion of higher education, a much larger number of engineering degrees in Germany resulted from the 1989 reunification of the former West Germany with the former East Germany, which—like many Central and Eastern European countries—had focused much of its higher education on engineering. (See NSF 1996a and appendix table 2-1.)

North America

Trend data on Canada, Mexico, and the United States show a decline in earned undergraduate degrees in NS&E from 1986 to 1994.[6] This decline is partly accounted for by changes in the demographics of the United States and Canada: specifically, the decline in college-age population that began in the mid-1980s. (See appendix table 2-3.) Initially, this downturn in the college-age cohort was offset by increasing access to higher education among all subpopulations. However, this broader access and increased enrollment in higher education did not result in larger numbers of bachelor's degree

[5]Western European countries are those within the European Union and the European Free Trade Association. (See appendix table 2-1.)

[6]Data are from NSF (1997a), unpublished tabulations.

Growth in Institutions of Higher Education in Asia

The expansion of higher education institutions in Asia, particularly for graduate programs, has been financed by government (Japan), by industry (South Korea), and through international loans (China).

Japan. Japan greatly expanded its institutions of higher education in the 1950s. By 1955, there were over 100 public institutions, including both local and national universities. The number of public institutions has not significantly increased since then. In all, 25 national universities and 15 local universities have been opened in the last 40 years. In contrast, the number of private institutions has increased rapidly in the last few decades, reaching over 400 in 1995, and accounting for around 75 percent of all higher education institutions (Monbusho 1995). National universities, however, dominate in the production of doctoral degrees, accounting for 85 percent of NS&E degrees (Monbusho 1995).

About 30 of Japan's national universities are considered research universities. In the 1970s, the government Ministry of Education, Science, and Culture began building national inter-university research institutes open to all university researchers. These provide large-scale, well-equipped research facilities that can be used for international collaboration in specific fields. The first of these inter-university research institutes was the National Laboratory for Higher Energy Physics. These institutes, now numbering 15, have the same status as national universities (Monbusho 1995).

The main science funding agencies in Japan have sharply increased the amount of competitive research funding to universities to improve research facilities and personnel. About a half-dozen research institutes have received large five-year infusions of funds to enable them to become centers of excellence in specialized fields—e.g., brain research, material science, and econometrics (NSF 1997c).

South Korea. The most prestigious institutes of higher education in South Korea are those few national universities that survived the 1905-45 Japanese occupation. However, a substantial network of new higher educational institutions was created after the Korean War, consisting of 134 colleges and universities, and 152 junior colleges. The latter play a key role in the education of scientists and engineers. In fact, much of the recent rise in postsecondary educational attainment is seen at the junior college level, where enrollment nearly doubled between 1990 and 1996 (Government of the Republic of Korea 1996).

South Korea has also expanded graduate S&E programs. In the 1980s, the Korean Advanced Institute of Science and Technology was established to increase support for postgraduate training within South Korea. More recently, Pohang University of Science and Technology was established by the industrial giant, Pohang Iron and Steel Corporation, much as institutions such as Stanford and Carnegie-Mellon were founded by early U.S. industrialists.

China. In the 1980s, the extensive infrastructure for graduate training in China was strengthened, after having been greatly disrupted during the late 1950s and the Cultural Revolution of the 1960s. China's policy of modernization through science and technology resulted in a massive investment in higher education institutions, particularly to increase enrollments in S&E at the undergraduate and graduate levels. The expansion and upgrading of such institutions were partially financed by a series of international loans from the World Bank; from 1981 to 1991, these loans totaled $1.2 billion. (See text table 2-2.)

China specifically requested international development assistance loans for higher education as part of its economic plan to bolster its high-technology manufacturing sectors. The loans improved research instrumentation and computing facilities, allowed both senior scholars and younger students to study abroad, and provided for several hundred international advisors to assess departments and advise on curricular reform (Hayhoe 1989).

Part of China's strategy was to improve the quality of teaching and research in higher education by sending selected students to study in foreign universities, especially in NS&E fields. At first, most students and research scholars were government supported and returned to China after their studies. Between 1979 and 1988, approximately 19,500 Chinese scholars and graduate students who had studied in the United States returned to China; they subsequently became an important component of China's science and technology resources (Orleans 1988). Currently, only a small fraction of Chinese foreign students are government supported, and return rates to China are low. (See "Stay Rates of Foreign Doctoral Recipients in the United States" later in this chapter.)

There are more than 1,000 higher education institutes in China. Seventy of them provide four-year university programs; 43 are comprehensive universities. In 1988, about 86 of China's higher education institutions were singled out as centers of excellence for priority funding (NSF 1993).

Text table 2-2.
Recent World Bank education projects in China
(Millions of current U.S. dollars)

Project topic	Total	Loan	Credit	Years
University development I	200	100	100	1981-86
Agricultural education/ research I	75		75	1982-88
Polytechnic/TV university	85		85	1983-89
Agricultural education II	69	45	24	1984-89
Rural health and medical education	85		85	1984-89
Agricultural research II	25		25	1984-89
University development II	145		145	1985-90
Provincial universities	120		120	1985-90
Technical education	130		130	1987-91

NOTE: Loans are funded by the World Bank's International Bank for Reconstruction and Development at commercial rates. Credit is provided by the World Bank's International Development Association; this funding is interest free and has lengthy repayment terms.

SOURCE: R. Hayhoe, *China's Universities and the Open Door* (Armonk, NY: M.E. Sharpe, Inc., 1989).

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Growth in Institutions of Higher Education in Europe

In the 1960s, the accelerated pace of European economic development created a demand for more skilled labor, and the expansion of the middle class caused a great demand for higher education. Governments in Europe responded to these pressures by forming so-called "non-university" tertiary level institutions, such as the *Instituts Universitaires de Technologie* in France in 1966, polytechnics in the United Kingdom in 1969, and the *Fachhochschulen* in Germany in 1971 (Academia Europea 1992). The small number of students in secondary and higher education in these countries began to expand. Similar institutions arose throughout other Western European countries during this period, thus broadening the student base in higher education. The largest numbers of institutions are found in Germany, France, and the United Kingdom.

Germany. German higher education takes place at 251 institutions, among them 125 *Fachhochschulen* and 70 universities, including 6 private universities. Only university graduates may continue their studies through doctoral programs. The university degree in Germany requires a minimum of 4 years of study; the average length of undergraduate study is 6.5 years. This lengthy first university degree reflects both the quality of university education and the great overcrowding of universities, a phenomenon that occurs throughout Europe. University education is funded by the federal government and the *Lander* (states), and the numbers of institutions and faculty positions have not expanded in proportion to the increasing number of students (Von Friedeburg 1991). The German Government has established 26 new *Fachhochschulen* in the former East Germany to create a more highly skilled labor force and to foster economic growth in that region (Government of the Federal Republic of Germany 1994).

France. Institutions of higher education in France include universities; technical institutes; and *Grandes Écoles* of engineering, business, and administration. The vast majority of students are in universities; only 90,000 students attend the prestigious *Grandes Écoles* (Feldman and Morelle 1994). Postsecondary two-year technology programs grew rapidly in the 1980s at the University Institutes of Technology and the *Sections de Technicien Supérieur* (Charlot and Pottier 1992).

United Kingdom. Until recently, higher education institutions in England and Wales were divided into three sectors: universities, polytechnics, and colleges. Most provide three-year degrees (following a 13-year elementary and secondary program), although degree awards in NS&E fields usually take four years. The universities are the longest established of the three sectors. Colleges were founded in the late 19th century for training personnel for local employers. Thirty polytechnics were created in the 1960s to broaden access to higher education for groups traditionally underrepresented. They originally were to have a vocational focus, but the course offerings of the polytechnics have gradually become similar to those of universities. In 1992, most polytechnics attained university status. The 46 existing universities retained their role as prime providers of research and still account for the large majority of natural science degrees. Only about half of all engineering and computer science degrees are obtained in universities, however; the other half are obtained in polytechnics and specialized colleges (Tarsh 1992).

(For more information on institutions of higher education in Germany, France, and the United Kingdom, see NSF 1996a.)

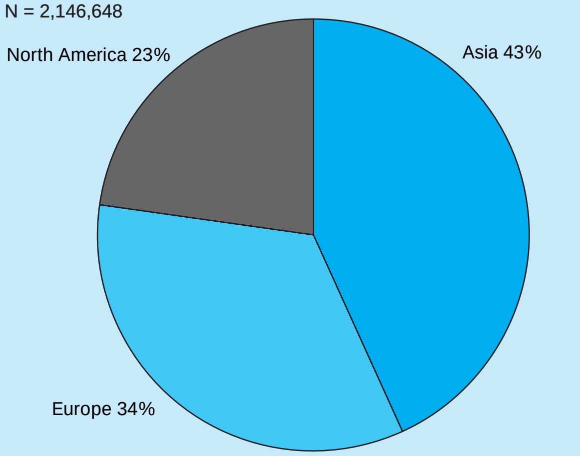
completions in S&E fields. In the United States, the ratio of NS&E degrees to total first university degrees has declined from 21 percent in 1987 to 15 percent in 1995. (See NSF 1993 and appendix table 2-6.) In contrast, Mexico has had an increasing college-age cohort and an expansion of earned university degrees from 1980 to 1992, particularly in engineering. Recent data from Mexico (1993 and 1994) show a decline in NS&E degrees, but this is due to major changes in taxonomies used in the classification of NS&E degrees and in the graduation requirements within Mexico's university system. (ANUIES 1996b.)

Regional Proportions of S&E Degree Production

Opportunities for S&E education are increasing throughout the world, consequently, the U.S. proportion of the total is decreasing. In 1995, earned degrees in S&E in the North American region represented 23 percent of the three-region total. (See figure 2-2.) The United States represented less than 18 percent of such earned degrees. In considering only NS&E fields (excluding the social sciences), the U.S. proportion is even smaller.

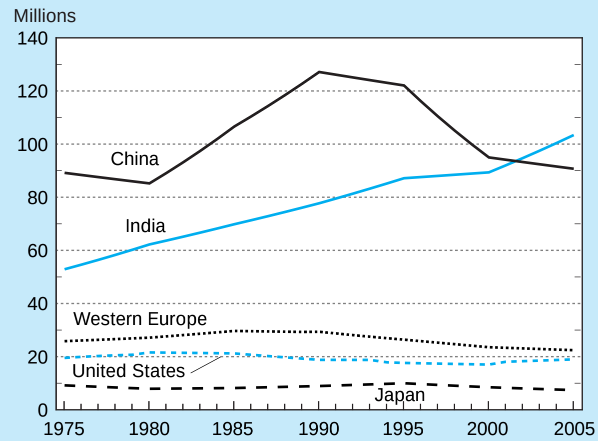
Even though the lack of time-series data for all countries in these regions prevents a statistically sound comparison of regional proportions from an earlier period, the higher rate of change in the distribution of S&E degrees over time in other world regions has implications for the United States and other countries. The global diffusion of S&E education also has implications for the U.S. higher education system. Other countries' increasing capacity to educate in advanced levels of S&E helps explain the decline in foreign student enrollment in engineering programs in the United States. (See "Bachelor's Degrees in S&E" and "Trends in Graduate Enrollment" later in this chapter.) In addition, the continuing expansion of global capacity for S&E education has implications for all nations, since it indicates an increased potential for technological and economic development worldwide.

Figure 2-2.
First university degrees in S&E in three world regions: 1995 or most recent year



See appendix table 2-1. *Science & Engineering Indicators – 1998*

Figure 2-3.
Trends in population aged 20-24: 1975-2005



See appendix table 2-3. *Science & Engineering Indicators – 1998*

Reasons for the Global Increase in S&E Education

Demographics

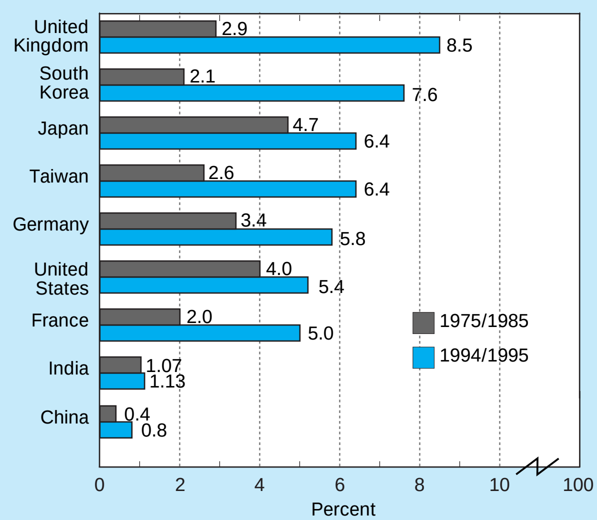
The increase in S&E degree production in Asia is driven by the expansion of access to higher education for large or growing populations. Developing countries such as India and China have large populations in their college-age cohort and increasing participation rates in postsecondary education, while the industrialized countries of Japan, Western Europe, Canada, and the United States have declining student populations. Trend data on China's 20- to 24-year-old population show a decline from 1990 to 2005, but the number in this age segment is over 100 million for 1998. India's college-age cohort will have increased to 88 million by 1998. In contrast, the college-age population in Western European countries as a whole has declined from 30 million in 1985 to 25 million in 1998, and will continue to decline until 2005. The U.S. college-age cohort has been decreasing since 1980, and will continue to do so until 2000, when this age segment will slowly begin to rise. Japan's college-age population (10 million in 1995) will decrease by 30 percent in the next 15 years. (See figure 2-3 and appendix table 2-3.)

Increasing Participation Rates in NS&E Degrees

Taiwan and South Korea dramatically increased their production of NS&E degrees from about 2 percent of their 24-year-olds in 1975 to 6 and 7 percent, respectively, in 1995. (See figure 2-4.) Japan has consistently had a high percentage of its 24-year-olds completing NS&E degrees since the 1970s; a slight decline in NS&E recipients in the late 1980s was followed by yet more growth in the 1990s. (See appendix table 2-1 for 1995 data and NSF 1993 for trend data on Asian countries.)

Asia's two population giants, India and China, have low attainment rates of NS&E degrees. India, with its huge, growing

Figure 2-4.
Proportion of 24-year-olds earning NS&E degrees, by country



NOTES: European data are for 1975 and 1994; Chinese data are for 1985 and 1995. Other countries' data are for 1975 and 1995. NS&E is natural sciences and engineering.

SOURCES: National Science Foundation, Science Resources Studies Division (NSF/SRS), *Human Resources for Science and Technology: The Asian Region,* NSF 93-303 (Washington, DC: 1993); and NSF/SRS *Human Resources for Science and Technology: The European Region*, NSF 96-319 (Arlington, VA: 1996); and appendix table 2-1.

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population, is maintaining its participation rate of 1.1 percent. In 1985, just under 0.9 percent of China's college-age population earned a bachelor's degree, and approximately 0.5 percent earned a degree in an NS&E field. Within a decade, these percentages rose to 1.3 percent with a bachelor's degree and 0.8

percent with an NS&E degree, although participation rates are still far lower than those for developed countries. (See appendix table 2-1; see NSF 1993 for trend data on Asian countries.) If China continues to increase its participation rate in NS&E degrees, and India can maintain its current rate with a growing population, the world stock of science and engineering graduates will be greatly augmented, and the U.S. share of S&E degrees will be reduced.

A declining pool of college-age students in Europe has not resulted in declining numbers of NS&E degrees, as has occurred in the United States. Rather, participation rates in higher education and NS&E degrees, previously low, have grown to more than offset the declining population. In Finland, for example, 9 percent of the college-age cohort obtains a university degree in the natural sciences or engineering—one of the highest participation rates in the world.

Differences in Participation Rates by Sex

The growth in participation rates in NS&E degrees differs considerably for males and females across countries. Japan shows the largest disparity in completion of NS&E degrees by males and females of college age. In 1995, more than 11 percent of males in the college-age population earned an NS&E degree. One percent of Japan's females earned such a degree. South Korea has a similarly high percentage of college-age males earning an NS&E degree, and 4 percent of its female college-age population earned such a degree. In the United States, 7 percent of college-age males earned an NS&E degree, as did almost 4 percent of females. (See appendix table 2-4.)

In countries of the three world regions examined, women have been particularly successful in earning degrees in the natural sciences and the social sciences. By 1995, women earned 50 percent of the natural science degrees in higher education institutions in the United Kingdom, 54 percent in Italy, 47 percent in the United States, and 44 percent in South Korea. In most countries in the three regions, women have also earned the majority of first university degrees in the social sciences. The notable exceptions are Japan and South Korea, where women earn only a modest proportion of social science degrees—19 and 27 percent, respectively. Women in all countries are considerably less likely to earn degrees in engineering. (See appendix table 2-5.)

Focus on S&E in Higher Education

Part of the reason for this rapid Asian growth has been the greater focus on these fields within Asian universities, with high quotas set for enrollments in these departments. Reflecting China's strategy to develop its economy through science and technology (see "Growth in Institutions of Higher Education in Asia"), 72 percent of its first university degrees are earned in S&E fields. In addition, about 67 percent of Japanese degrees and 46 percent of South Korean were in these fields. Among European countries, 46 percent of first university degrees in Germany and Finland are in S&E. Russia and Central and Eastern European countries are similarly focused on science and engineering. In contrast, less than one-third of first university degrees (bachelor's degrees) in the United States are earned in S&E. (See appendix table 2-6.)

Characteristics of U.S. Higher Education Institutions

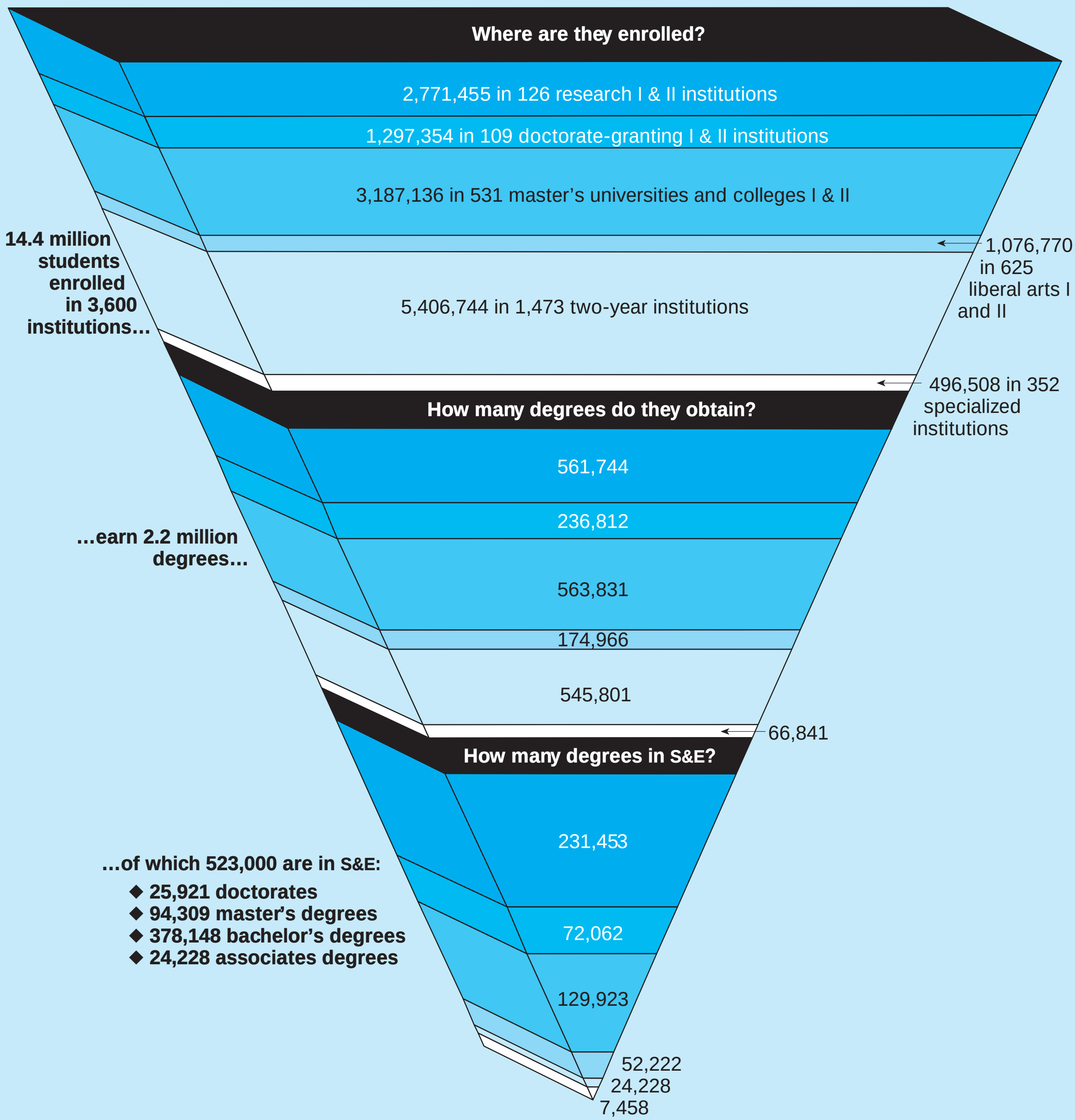
The United States has a large and diversified set of institutions of higher education that provides a college or university education to over one-third of the U.S. college-age population. (See appendix table 2-1.) This access to higher education ranks the United States among those countries with the most open education systems in the world.

In the United States, there were 3,681 (1,594 public and 2,087 private) institutions of higher education in 1995 (HEP 1997). These institutions enrolled 14.4 million students at all degree levels (associate, bachelor's, master's, and doctoral) in that year and awarded 2.2 million degrees, almost one-quarter of which were in S&E. (See figure 2-5.) The Carnegie Foundation for the Advancement of Teaching has classified these institutions into 10 categories based on the size of their baccalaureate and graduate degree programs, the amount of research funding they receive, and—for baccalaureate colleges—their selectivity.[7] Following is a brief description of these categories.

- ♦ ***Research universities I.*** These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate, and give high priority to research. They award 50 or more doctoral degrees each year, and receive $40 million or more annually in federal support.
- ♦ ***Research universities II.*** These institutions are the same as research I, except that they receive between $15.5 million and $40 million annually in federal support.
- ♦ ***Doctorate-granting I.*** In addition to offering a full range of baccalaureate programs, the mission of these institutions includes a commitment to graduate education through the doctoral degree. They award 40 or more doctoral degrees annually in at least five academic disciplines.
- ♦ ***Doctorate-granting II.*** These institutions are the same as doctorate-granting I, except that they award 20 or more doctoral degrees annually in at least one discipline or 10 or more doctoral degrees in three disciplines.
- ♦ ***Master's (comprehensive) universities and colleges I.*** These institutions offer baccalaureate programs and, with few exceptions, graduate education through the master's degree. More than half of their baccalaureate degrees are awarded in two or more occupational or professional disciplines, such as engineering or business administration.

[7]The Carnegie classification is not an assessment guide, nor are the distinctions between classification sublevels (e.g., research I and research II) based on institutions' educational quality. Baccalaureate college I institutions exercise more selectivity regarding students than do baccalaureate colleges II, but in general the Carnegie categories are a typology, not a rank ordering.

Figure 2-5.
U.S. higher education in 1995: Students, institutions, and degrees



NOTE: This figure represents relative sizes of enrollments and degrees within Carnegie categories of institutions in 1993. It does not depict the dynamics of higher education or the movement of students among institution types prior to graduation.

See appendix tables 2-8, 2-9, 2-10, and 2-18.

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The U.S. Higher Education System

The U.S. system of higher education is characterized at the undergraduate level by diverse institutions that provide flexible access to higher education for a broad range of U.S. citizens. At the graduate level, the system serves not only U.S. students but international students as well. Demographic changes (for example, a pending upturn in the population of college-age students, with higher percentages of minorities underrepresented in S&E), the increasing capabilities of other nations, and job-seeking experiences of recent graduates are prompting a reexamination of the U.S. system of higher education.

At the undergraduate level, the U.S. system provides access for a broad cross-section of citizens. About one-third of the college-age cohort completes a college or university education in some field. Although some European countries are approaching this high level of access, the European region as a whole reaches only about half that proportion of its college-age cohort. Contributing to this broader U.S. access is the expansive institutional base of U.S. higher education, which allows for flexibility in transferring among institutions and diverse attendance patterns. Over one-third of the 15 million students in U.S. higher education are in community colleges. These institutions let students transfer credits to four-year colleges and universities; they also provide considerable remedial coursework for students who were not well-served by, or well-motivated during, their high school education. (Chapter 1 discusses this phenomenon, with particular reference to middle and high school teachers teaching out of their field, especially in math and science.)

This expansive institutional base, however, is also characterized by uneven quality and highly differential resources. Many minority students are in community colleges; although this can facilitate their continuation in the higher education system, this level of the system is the most poorly funded and has the worst track record for graduation. Only a small percentage of minority students or students from poor families completes an associate degree in an S&E field and subsequently enters a four-year institution. Moreover, since most mathematics courses at the community college level are remedial, they are not transferable to four-year institutions. This route in the U.S. higher education system has not yet resulted in commensurate representation of minority groups in earned degrees in science, mathematics, and engineering. (See “S&E Human Capital Development: Continued Unevenness Across Demographic Groups” later in this chapter.)

With its blend of advanced coursework and research experience, U.S. graduate education in S&E is considered to be among the best in the world. In the last 10 years, U.S. graduate programs have expanded, particularly at the doctoral level. Academic R&D has also grown during this period, and an increasing number of foreign students have enrolled in U.S. graduate S&E programs. Between 1985 and 1995, the number of doctoral degrees awarded in engineering, mathematics, and the computer sciences doubled. Much of this growth was due to foreign doctoral recipients, many of whom earned their S&E degrees while supported as research assistants. Postdoctoral positions increased at almost the same rate, and foreign students earned an increasing proportion of these appointments—slightly more than half by the 1990s. (See chapter 5, “Integration of Research With Graduate Education.”) Beginning in 1993, however, foreign student enrollment in U.S. graduate S&E programs experienced a decline, which, if it continues, will reduce the proportion of S&E degrees and postdoctoral appointments awarded to foreign students.

Decisionmakers throughout the U.S. higher education system are examining both undergraduate and graduate levels to broaden participation of all groups in science and engineering, and to broaden career choices for those with advanced degrees. At the undergraduate level, a revitalization of science and mathematics curricula is aimed at better teaching of all students, enhanced teacher preparation for K-12 programs, and greater retention of students in S&E departments. Educators are forming partnerships between the faculties of two- and four-year schools to improve academic courses at community colleges and establish agreements for transferring credits. In graduate education, the appropriateness of current training for careers in industry as well as in academia is being examined.

Reforms in U.S. higher education are particularly important in light of ongoing demographic changes. A two-decade-long decline in the college-age cohort in the United States reduced the traditional college-age population from 22 million in 1980 to 17 million in 1995. This declining trend is expected to reverse itself in the year 2001. The projected increasing student population will then create a demand for yet further expansion of the U.S. higher education system.

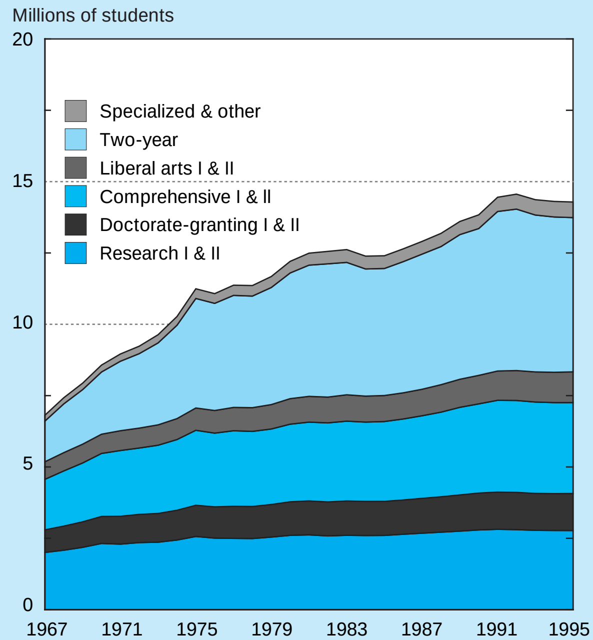
All of the institutions in this group enroll at least 2,500 students.

- ***Master's (comprehensive) universities and colleges II.*** These institutions are the same as master's universities and colleges I, except that all of the institutions in this group enroll between 1,500 and 2,500 students.
- ***Baccalaureate (liberal arts) colleges I.*** These highly selective institutions are primarily undergraduate colleges and award more than 40 percent of their baccalaureate degrees in liberal arts and science fields.
- ***Baccalaureate (liberal arts) colleges II.*** These institutions are primarily undergraduate colleges that award less than 40 percent of their degrees in liberal arts and science fields. They are less restrictive in admissions than baccalaureate colleges I.
- ***Associate of arts (two-year) colleges.*** These institutions offer certificate or degree programs through the associate degree level and, with few exceptions, offer no baccalaureate degrees.
- ***Professional schools and other specialized institutions.*** These institutions offer degrees ranging from the bachelor's to the doctorate. At least half of the degrees awarded by these institutions are in a single specialized field. These institutions include theological seminaries, bible colleges, and other institutions offering degrees in religion; medical schools and centers; other separate health profession schools; law schools; engineering and technology schools; business and management schools; schools of art, music, and design; teachers' colleges; and corporate-sponsored institutions.

After several decades of continual and rapid expansion of higher education in the United States, enrollment fell for the first time in 1993; it has continued to decline each year since then. (See figure 2-6 and appendix table 2-8.) This decline is partially based on demographics: the U.S. college-age population declined from 22 million in 1980 to 17 million in 1995. (See appendix table 2-3.) However, the decline in the college-age population was offset for over a decade by expanded access to higher education for all subpopulations, particularly women and minorities, and enrollment by larger numbers of older students. The U.S. college-age cohort will again increase beginning in 2001, and higher education enrollments are expected to increase concurrently.

A diverse spectrum of institutions contributes to the S&E degrees in the United States. The country's 126 research universities provide the majority of engineering degrees and a large proportion of natural and social science degrees at both the graduate and undergraduate levels. (See figure 2-7.) In 1995, research universities enrolled only 19 percent of all students in higher education, but produced over 46 percent of all S&E degrees. (See appendix tables 2-8 and 2-9.) In contrast, the associate of arts colleges enroll a large proportion of all students in higher education, but account for only a small percentage of S&E degrees. In 1995, only about 10 percent of the over 5.4 million students attending junior colleges completed an associate degree—less than 1 percent in an S&E field. These two-year colleges, however, provide continuing education and flexibility in the U.S. higher education system, allowing students to complete needed work-related courses or to obtain credits for transfer to a four-year college or university. (See "The U.S. Higher Education System.")

Figure 2-6.
U.S. enrollment in higher education, by institution type



See appendix table 2-8. *Science & Engineering Indicators – 1998*

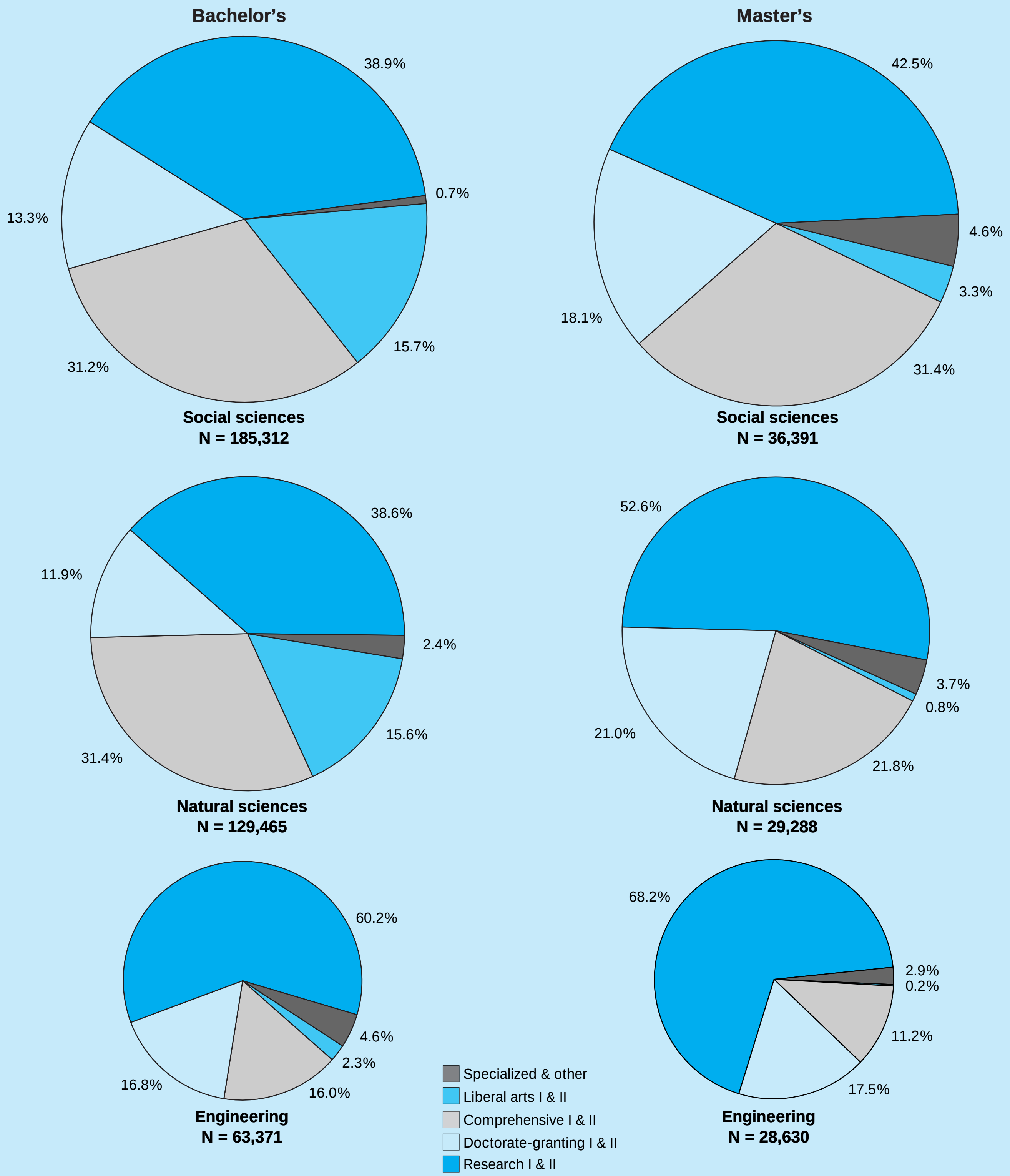
Undergraduate S&E Students and Degrees in the United States

Recent Trends in College Enrollment

For almost a decade starting in 1984, undergraduate enrollment in U.S. institutions of higher education showed strong growth, peaking in 1992 with nearly 12.7 million students. Undergraduate enrollment has declined slightly each year since, mainly from the decrease in the college-age cohort of the majority (white) population. The continuing increase in enrollment for all minority groups did not make up for the loss of white enrollment, resulting in an overall decrease.

The trend of increasing enrollment in undergraduate programs by underrepresented minorities has persisted for over a decade and accelerated in the 1990s. Black enrollment increased 3.6 percent annually in the 1990s, reaching 1.3 million in 1995. In the same period, Hispanic enrollment in higher education increased at an even faster rate (7.1 percent annually.) These

Figure 2-7.
Bachelor's and master's degrees awarded in S&E, by institution type: 1995



NOTE: Natural sciences here include mathematics and computer sciences.

See appendix table 2-9.

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national trend data bear watching as some states change affirmative action programs. Undergraduate enrollment of foreign students grew very modestly in the past two decades; in 1995, foreign students still represented only 2 percent of total undergraduate enrollment. (See appendix table 2-11.)

Characteristics of American College Freshmen Planning to Major in S&E

Need for Remedial Work in Mathematics and Science

One indicator of the readiness of American students for college-level S&E courses is their self-reported need for remedial work in mathematics and science. The percentage of freshmen reporting a need for such remedial work has remained high, particularly for women and minorities. In 1995, of those freshmen planning to major in science or engineering, over 16 percent of the males and over 26 percent of the females thought they would need remedial work in math. Among freshman students from underrepresented minority groups planning to major in S&E, over 38 percent reported that they would need remedial work in math. This self-reporting of the need for remedial work differed by planned major. Fewer of the students planning a major in the physical sciences or engineering reported needing remedial math, as compared to those planning a major in the social or biological sciences. (See figure 2-8.) Over 20 percent of minority students planning a major in the biological sciences or engineering thought they would need remedial work in science.

Freshmen Intentions to Major in S&E

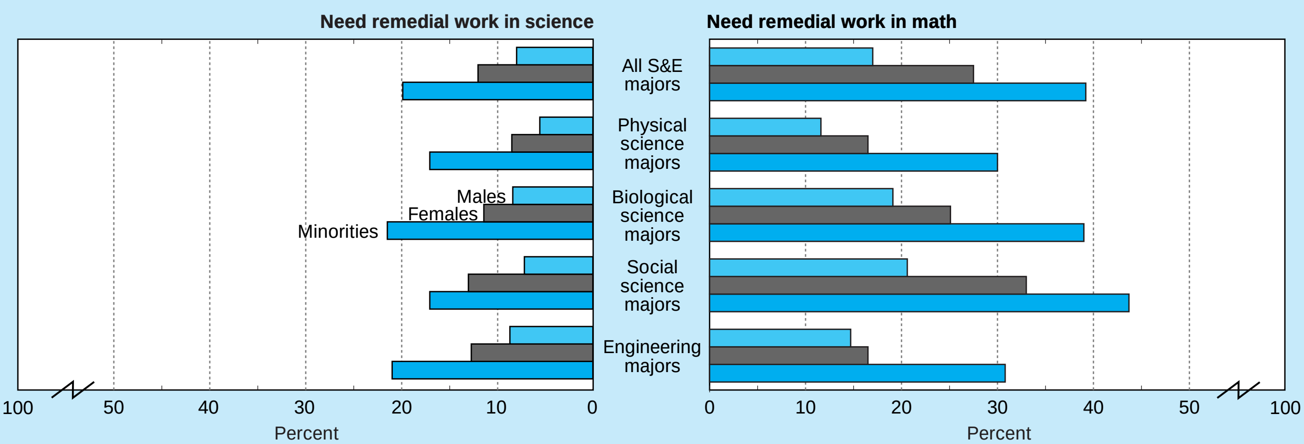
Among the majority (white) population, about one-third of the freshman have traditionally contemplated a major in an S&E field; most of these intend to major in a field of natural or social science, with smaller percentages selecting mathematics, the computer sciences, or engineering. From the late 1970s on, the percentage of freshmen planning an engineering major has remained relatively constant, at around 9 percent. During the same period, mathematics and computer sciences have been the intended majors of around 2 percent of incoming freshmen. Freshmen have fluctuated more in their choice of natural science and social science majors. After a decade-long decline in the selection of natural sciences as a possible major, the trend reversed in 1987, increasing to around 12 percent by 1996. The social sciences have become more attractive majors, but not as popular as the natural sciences. (See appendix table 2-15.)

Planned Majors and Completion Rates by Sex and Race/Ethnicity

Trends in freshman choice of major show differences by sex and race/ethnicity. Asian American students are moving away from a very high concentration of S&E majors—particularly in engineering—and are majoring in a broader range of fields. While still relatively high, the proportion of Asian American males choosing engineering as freshmen declined from 38 percent in 1980 to 23 percent in 1996. For many years, higher proportions of black and Hispanic males have chosen engineering than have white males, and a higher proportion of black females than white females have chosen to major in mathematics and computer sciences. Women of every race/ethnicity, however, show an increase in choice of natural sciences. (See appendix table 2-15.)

An increasing proportion of those students planning to major in S&E fields are from underrepresented minority groups. In 1996, underrepresented minorities accounted for 15 to 21 percent of those planning to major in the following fields: physical sciences, biological sciences, social sciences, and

Figure 2-8.
Freshmen reporting need for remedial work in science or math, by intended major: 1995



NOTE: As used here, minorities are those underrepresented in S&E: blacks, Hispanics, and Native Americans.

See appendix table 2-17.

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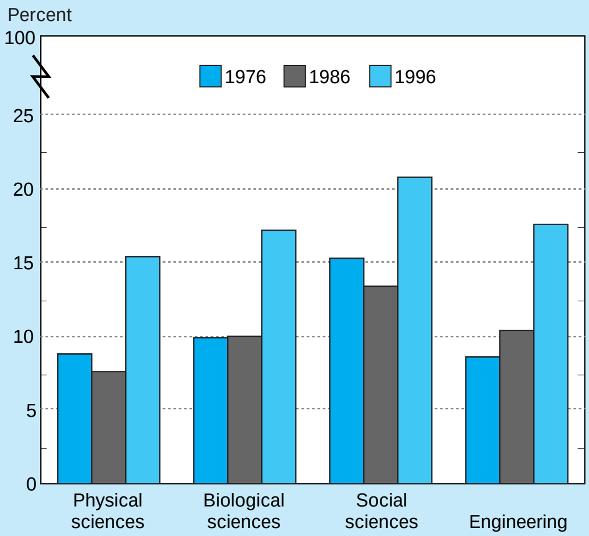
Figure 2-9.
Minority representation among freshmen planning to major in an S&E field



NOTE: As used here, minorities are those underrepresented in S&E: blacks, Hispanics, and Native Americans.

See appendix table 2-16. *Science & Engineering Indicators – 1998*

engineering. In 1976, underrepresented minorities accounted for between 9 and 15 percent of those planning to major in these fields. (See figure 2-9.)

A substantial fall-off occurs between freshmen declaration of intent to study S&E fields and actual completion of S&E degrees (Astin and Astin 1992).[8] This fall-off differs by race, particularly in NS&E fields. There is some fall-off among the majority (white) students: 12 percent intend to major in natural sciences and 9 percent in engineering, but only 8 percent of degrees earned by white students are in the natural sciences and only 5 percent in engineering. A larger fall-off occurs among underrepresented minority groups. Ten percent of black students intend to study a field of natural science, but only 5 percent of degrees earned by blacks are in these fields. Further, 9 percent of black students intend an engineering major, but only 3 percent of undergraduate degrees earned by black students are in engineering. (See appendix tables 2-15 and 2-21.)

Engineering Enrollment

Engineering programs require students to declare their major as freshmen, allowing engineering enrollment to be used as an early indicator of undergraduate degrees. The composition of enrollment can also be used as an indicator of participation rates of women and minorities. Undergraduate engineering enrollment declined from a high of 441,205 students in 1983 to 356,177 students in 1996, representing a 19 percent reduction. The decline was neither smooth nor continuous. Engineering enrollment stabilized for several years (1989 to 1992) before resuming its decline. Part-time student enrollment, which accounts for about 10 percent of overall enrollment, has remained relatively stable during the last decade. The relative steadiness of engineering enrollment in the early 1990s is reflected in the stable number of engineering degrees in the 1993-95 period. (See appendix tables 2-13 and 2-20). However, the decline in overall engineering enrollment from 1993 portends a decline in engineering degrees at the end of the decade and in the year 2000.

While overall undergraduate engineering enrollment has been declining, enrollment of women and minorities has been increasing, particularly in the 1990s. The number of female students enrolled in engineering increased from 61,000 in 1990 to 68,000 in 1996. For underrepresented minorities, the increase was greater, from 41,000 in 1990 to almost 54,000 in 1996. By 1996, female students represented 19 percent of total undergraduate engineering enrollment, and underrepresented minorities represented 15 percent of such enrollment. Concurrently, the number of foreign students enrolled in U.S. undergraduate engineering programs has been decreasing, in response to enhanced capacity in engineering programs abroad. (See figure 2-10 and appendix table 2-14.)

Science and Mathematics Coursetaking

Universities strive to address the academic needs of students in all majors. In addition to S&E, disciplines that require a grounding in mathematics and science include K-12 education, business, and law, among others. With the increasing interplay of science and technology in our society, all citizens benefit from a higher level of technological literacy and an understanding of the methods and processes of science.

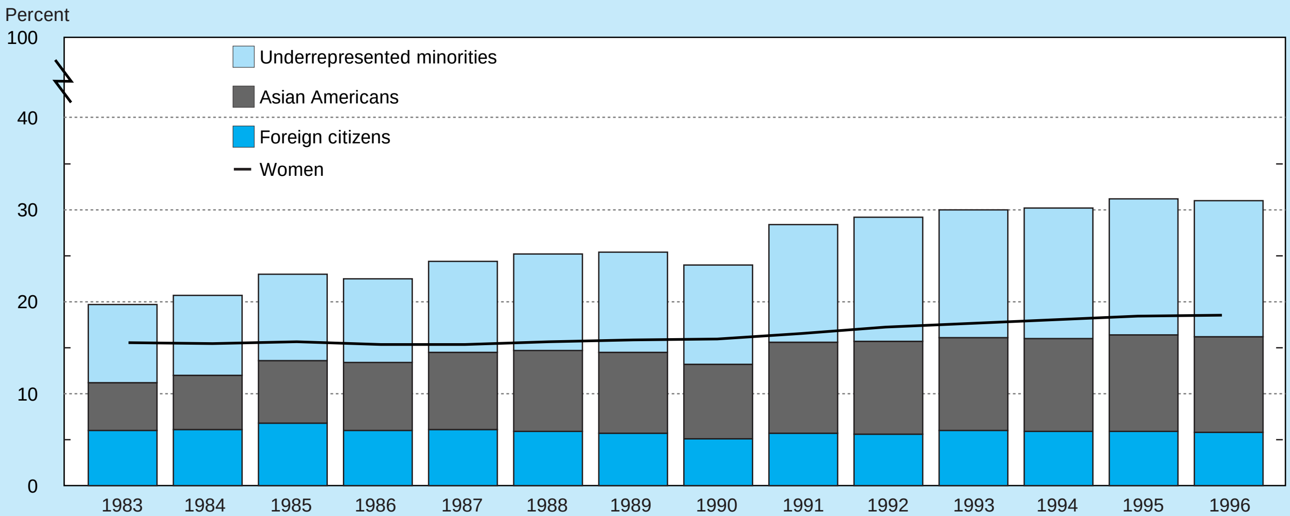
Curricular Reform

In the 1990s, many S&E departments have designed or adapted new curricula to broaden the attraction to, and success with, science and engineering courses. For example, several academic institutions have initiated "calculus reform," a movement to align calculus instruction more closely with theories of how students learn; others have created multimedia software modules to enhance visualization for students not majoring in science. A large number of institutions have adopted or designed revitalized curricula or variations of these reforms. (Advisory Committee to NSF/EHR 1996). By 1995, 22 percent of the 372,000 students enrolled in calculus 1 and 2 were using a reform text[9] along with various other innovations, such as graphing calculators, writing and computer assignments, and group projects (Rung 1997).

[8]Freshman intention data are estimates based on a sample of surveyed students, while degree data are the universe of earned degrees. Therefore, the fall-off in percentages for intentions and actual degrees cannot be measured precisely. Further, the data are not limited to freshmen who actually go on to earn degrees. The comparison does, however, show that there is a fall-off, and that the magnitude is greater for minority students.

[9]A text reflecting the pedagogical principles of the reform calculus movement.

Figure 2-10.
Representation of women and minorities in undergraduate engineering enrollments



NOTE: Minorities underrepresented in S&E are blacks, Hispanics, and Native Americans.

See appendix table 2-14. *Science & Engineering Indicators – 1998*

Number of Courses Taken in Science and Mathematics

Recent data from the Longitudinal Study of American Youth (LSAY) reveal some facts about coursetaking behavior in science and mathematics among those who attended two- or four-year colleges and universities. As expected, science, engineering, and mathematics majors report a far higher number of completed mathematics and science courses than non-S&E majors. Over half of the mathematics and engineering majors report five or more courses in mathematics. Over 90 percent of the science majors report five or more courses in science. However, many non-S&E majors are taking mathematics and science courses beyond the general education requirements (in a liberal arts program, typically two mathematics courses and two science courses to graduate). Over half of the education majors who earned a bachelor's degree took three to four mathematics courses, with over 40 percent taking three to four courses in science and 25 percent taking even more. (See appendix tables 2-22 and 2-23.)

Level of Mathematics Courses in Undergraduate Education

Every five years since 1970, the Conference Board of the Mathematical Sciences (CBMS) has conducted a survey of a sample of four-year college and university departments of mathematics and two-year college programs in mathematics. These data are important in estimating overall enrollment trends, as well as in breaking out trends in mathematics courses taken by level of difficulty. Estimates of overall enrollment in courses taken in mathematics departments in four-year institutions declined substantially from the peak years of 1985 and 1990, as fewer undergraduate students majored in mathematics or took calculus or advanced level coursework.

The CBMS data show that mathematical enrollment trends differed by level of institution as well as level of difficulty. Enrollment increased in precalculus courses designed primarily for liberal arts students in four-year colleges and universities, and in remedial mathematics courses in two-year colleges. In 1995, at the community college level, over half (57.8 percent) of the enrollment in mathematics classes was for remedial level courses. This high proportion of remedial mathematics at the community college level has existed since 1985. In 1970, remedial courses in community colleges represented about one-third of all mathematics courses. Within four-year college and university mathematics departments, the estimated enrollment in remedial level courses has remained at about 15 percent of total mathematics enrollment since 1980. The proportion of mathematics enrollment in advanced courses has remained within a range of 6 to 9 percent since 1980, with enrollment in precalculus and calculus each accounting for about 40 percent of total mathematics enrollment). (See text table 2-3.)

Associate Degrees in S&E

At the associate degree level, the number of degrees in engineering technology has fallen precipitously, from 51,000 earned degrees in 1983 to 39,000 degrees in 1995. (See appendix table 2-18.) Between 1994 and 1995, the number of degrees decreased in all fields of S&E. This decline in associate degrees in S&E holds regardless of race/ethnicity. (See appendix table 2-19.) The one exception is Asian American students: in the sciences, their number of earned degrees is increasing slightly.

Text table 2-3.
Estimated enrollment in undergraduate mathematics courses
(Thousands)

	Fall enrollments in math departments of four-year institutions					Fall enrollments in math programs of two-year institutions				
Course level	1970	1980	1985	1990	1995	1970	1980	1985	1990	1995
All math courses	1,188	1,525	1,619	1,619	1,469	555	925	900	1,241	1,384
Remedial	101	242	251	261	222	191	441	482	724	800
Precalculus	538	602	593	592	613	134	180	188	245	295
Calculus	414	590	637	647	538	59	86	97	128	129
Advanced	135	91	138	119	96	0	0	0	0	0
Other						171	218	133	144	160

NOTE: Precalculus-level mathematics courses include algebra and trigonometry courses, as well as courses for nonscience majors, finite mathematics, non-calculus-based business mathematics, and mathematics for prospective elementary school teachers.

SOURCE: D.C. Rung, "A Survey of Four-Year and University Mathematics in Fall 1995: A Hiatus in Both Enrollment and Faculty Increases," *Notices of the AMS,* Vol. 44, No. 8 (September 1997): 923-31.

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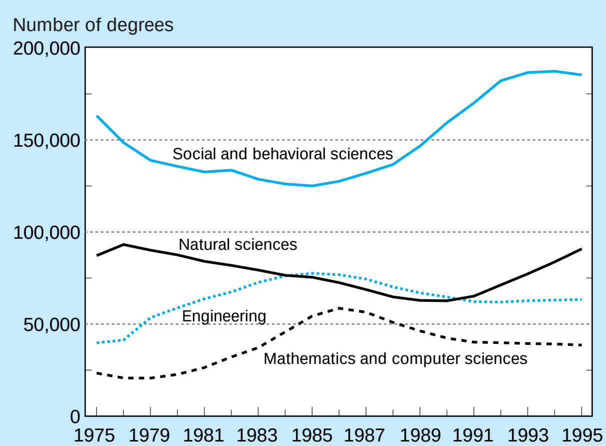
The declining trend in associate degree completions may be partly explained by the changing roles of junior colleges in the United States. Community colleges now go far beyond providing associate of arts degrees. They provide short courses, train in work-related technical skills, and serve as feeder schools to four-year colleges and universities. In contrast to the junior college level in many other countries— such as Japan and France—this level of higher education in the United States provides flexibility, allowing individuals to take courses outside of a degree program, as well as transition to more advanced levels of higher education. Many associate of arts colleges have an agreement with four-year schools to allow transfer of credits. For example, California encourages students to begin their college studies at a local community college, with the understanding that they will be admitted to a state university for their third and fourth years of a bachelor's degree.

Community colleges also pioneered distance learning to reach large numbers of students within their geographic region, and are partnering with universities to provide distance learning with local laboratory work. (See "Distance Learning and Its Impact on S&E Education.")

Bachelor's Degrees in S&E

Except for a brief decline between 1986 and 1989, the number of earned bachelor's degrees in S&E from U.S. institutions has been increasing for over a decade, rising from over 307,000 in 1981 to 378,000 in 1995. Trends in earned S&E degrees in U.S. institutions, however, differ widely by field. In the natural sciences, a long slow decline from 1976 to 1990 ended, shifting to an upturn in such degrees during the 1990s. Natural science degrees increased 7.7 percent annually from 1990 to 1995, with stronger than average growth in the biological and environmental sciences, but only modest (2 percent) growth in the physical sciences. The number of completed math and computer science degrees declined from 1975 to 1979, then climbed steadily reaching almost 59,000 degrees in the peak year of 1986. Attraction to the computer sciences dropped precipitously from 1986 to 1991, followed by slight decreases to 1995. The number of social science degrees awarded, after record growth between 1986 and 1992 (averaging 6 percent annually), has remained stable for the last four years. Engineering degrees, whose numbers also peaked in 1986 following a decade of strong growth—particularly in electrical and mechanical engineering—declined until 1991 and then stabilized. The slight annual growth rate in engineering degrees from 1991 to 1995 is mainly accounted for by the increasing number of degrees in chemical and civil engineering. (See figure 2-11 and appendix table 2-20.)

Figure 2-11.
Bachelor's degrees awarded in S&E



See appendix table 2-20. *Science & Engineering Indicators – 1998*

Distance Learning and Its Impact on S&E Education

Virtually all of the 300 engineering programs in the United States have some form of continuing education with distance learning for a local area; less prevalent but growing is generalized distance learning, with course material on the Internet. Students are increasingly participating in fully developed S&E lessons at home, at the office, in a library carrel, or even at another university. The impetus for distance learning stemmed from the responsibility of community colleges to serve a large number of students within a geographic region, and their need to develop off-site learning centers. In a 1991 survey by the American Association of Community and Junior Colleges, 80 percent of community colleges and 78 percent of universities had plans to provide distance learning by 1994 (Brey 1991).

S&E higher education has benefited from advances in distance learning. In the 1980s, television became an instrumental medium for developing courses and degree programs at the undergraduate and graduate levels. One example is the University of California at Davis Instructional Television program. Classes are broadcast live during the workday, and students usually enroll in one course per quarter. Full-time professional engineers obtain a master's degree in approximately three years and a doctoral degree within five to six years.

Telecommunications and satellite delivery make it possible for students to obtain their degrees almost anywhere in the world. Colleges and universities are using these support technologies to augment their existing distance learning programs—e.g., fax, CD-ROM, e-mail, two-way audio, and teleconferencing. (See text table 2-4.) For example, the National Technological University, a consortium of 47 leading engineering universities, offers 1,200 courses and 13 master's degree programs in science and engineering.

The Internet offers a fundamental advancement in distance learning delivery. The new Internet applications for audio, video, and two-way communication are expected to integrate the previous advancements in distance learning technologies into a single medium. Schools are beginning to experiment with on-line courses; for example, the University of Phoenix offers on-line courses that present workshops, homework, and even the final exam via the Internet. The Internet's impact on S&E higher education is not clear at this time, but several S&E associations are actively discussing its potential. (For more information, see chapter 8, "IT, Education, and Knowledge Creation.")

Text table 2-4.
Percentage of academic institutions using various technologies in distance learning programs

	Four-year universities		Two-year colleges	
Technology	1991	1994	1991	1994
Audio teleconferencing	30.0	37.0	12.0	25.0
Audiographics	10.0	22.0	5.0	14.0
Cable television	22.0	45.0	14.0	35.0
Compressed video/phone	13.0	35.0	3.0	16.0
ITFS	29.0	46.0	16.0	34.0
Microwave	25.0	37.0	12.0	27.0
Satellite (full motion)	33.0	52.0	15.0	30.0
Satellite (VSAT)	1.0	18.0	0.5	8.0

NOTES: Audio teleconferencing refers to telephone lines used to create interactivity among several sites. Audiographics is audio teleconferencing in conjunction with computer technologies to include graphics and still images. Compressed video/phone is compressed video via telephone lines. ITFS is instructional television fixed service (broadcast). Satellite (full motion) is full motion analog video transmission. Satellite (VSAT) is very small aperture terminals, interactive digital video network. 1994 data represent projected usage.

SOURCE: Ron Brey, "U.S. Postsecondary Distance Learning Programs in the 1990s: A Decade of Growth," a research project of the Instructional Telecommunications Consortium/American Association of Community and Junior Colleges (Washington, DC: American Association of Community and Junior Colleges, 1991).

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Bachelor's Degrees by Sex

These recent trends in earned degrees for S&E fields show a similar pattern for both males and females, with a few exceptions in the social sciences and engineering. After 1993, degrees earned by males decreased slightly in the social sciences, while females maintained their high number of degrees in these fields. In engineering, females increased their earned degrees in the 1990s, particularly in chemical and civil engineering. In the same period, degrees in engineering earned by males declined slightly. (See figure 2-12.)

Over the past two decades, the proportion of S&E degrees earned by females has increased considerably, particularly in the natural sciences and engineering. In 1975, females earned about one-quarter of the degrees in the natural sciences and 2 percent of those in engineering. By 1995, females earned 59 percent of social science degrees, 47 percent of natural science degrees, 35 percent of mathematics and computer science degrees, and 17 percent of the engineering degrees. (See appendix table 2-20.)

Bachelor's Degrees by Race/Ethnicity/Citizenship

Trends in S&E bachelor's degrees also differ by race/ethnicity, with white students earning fewer degrees in 1995 than in earlier years, and minority groups continuing their growth in earned degrees in these fields. The number of degrees earned by white students is slowly decreasing in all fields except the natural sciences.

In contrast, the number of degrees earned by underrepresented minorities in the United States—blacks, Hispanics, and Native Americans—is increasing slightly in NS&E fields and very rapidly in the social sciences. (See "S&E Human Capital Development: Continued Unevenness Across Demographic Groups.") In addition, the number of degrees earned by Asian Americans is increasing sharply in the natural and social sciences. (See appendix table 2-21.)

Foreign students have increased their earned degrees in the social sciences, but since 1981 have sharply decreased their degrees in engineering from U.S. institutions, as discussed in more detail below. The capacity to educate engineering students at the undergraduate level has increased dramatically in other world regions, and fewer foreign students are using U.S. universities for engineering education.

Participation Rates by Sex and Race/Ethnicity

The United States is one of the leaders in the world in providing access to higher education and ranks high among the major industrialized countries in the proportion of its population with an S&E background. These national statistics, however, do not apply to all fields or to all minority groups. In 1995, for the country as a whole, over 32 percent of the college-age population had completed a bachelor's degree in some field, and over 5 percent had earned a bachelor's degree in an NS&E field. But in that same year, only about 15 percent of black and Hispanic youth earned a college degree, and only about 2 percent of black and Hispanic youth earned a bachelor's degree in an NS&E field. In contrast, Asian

S&E Human Capital Development: Continued Unevenness Across Demographic Groups

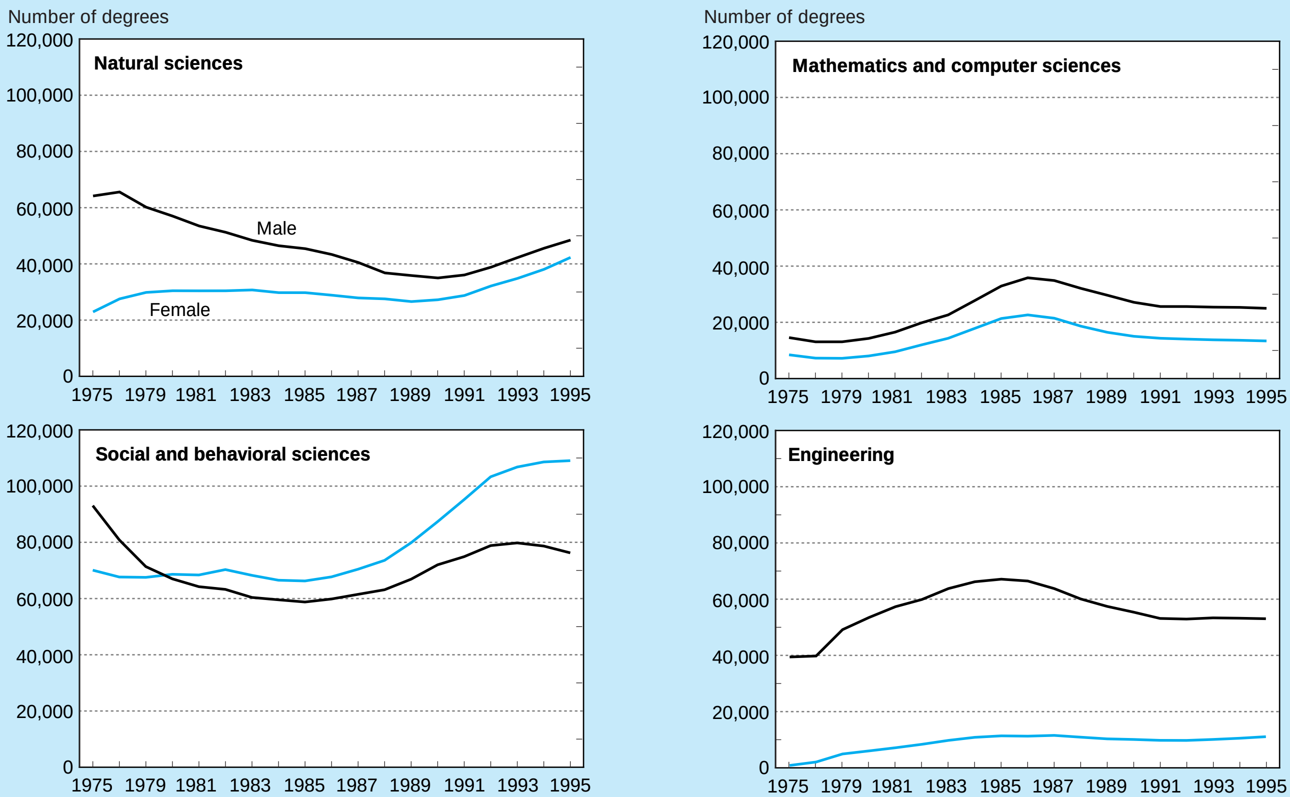
Beginning in the early 1980s, increasing numbers of women and minorities entered U.S. higher education. For a decade, the broadened entry of these groups fueled the expansion of enrollment in U.S. higher education and helped offset the trend of a declining U.S. college-age cohort. However, this broader access and increased enrollment in higher education did not concurrently result in larger numbers of S&E degree completions for women and minorities in all S&E fields at all levels. The pattern of participation is stronger in overall enrollment than in completed S&E degrees, stronger for females than for males in all underrepresented minority groups, stronger at the undergraduate than graduate level, and stronger in the natural and social sciences than in computer sciences and engineering.

Women. In the last decade, women achieved a higher rate of growth in undergraduate enrollment than men, particularly women in minority populations. Women now constitute 56 percent of undergraduate enrollment and an even higher percentage among minority populations. Women of every racial/ethnic group are increasingly choosing majors in the natural sciences and social sciences. At the bachelor's level, women now earn over half of the social science degrees and almost half of natural science degrees. However, women are less fully represented at the graduate level; in 1995, they accounted for 38 percent of total graduate enrollment. Women earned the majority of master's degrees in the social sciences and 41 percent of the master's degrees in the natural sciences. Women are least fully represented at the doctoral level. While women earn half of the doctoral degrees in the social sciences and 32 percent of the degrees in the natural sciences, they earn only 20 percent of the doctoral degrees in mathematics and computer sciences and less than 12 percent of doctoral engineering degrees.

Underrepresented minorities. The trend of increasing enrollment in undergraduate programs by underrepresented minorities has persisted for over a decade and accelerated in the 1990s, particularly for Hispanic populations. While minority groups indicate high aspirations to study S&E (as measured by freshman intentions), a substantial fall-off occurs between freshman declaration of intent and actual degree completion. This fall-off is greater for underrepresented minorities than for the majority population. Women and minority students are more likely to report a need for remedial work in mathematics and science than the majority male population. (Chapter 1 further discusses the large gap between minority students and the overall student population in number of science and mathematics courses taken.) There has been modest progress in minority participation in S&E degree completions. From 1975 to 1995, S&E bachelor's degrees earned by minorities increased from 6 to 8 percent of total such degrees. (Underrepresented minorities are around 28 percent of the college-age cohort.) Only about 2 percent of the 24-year-olds in underrepresented minority populations hold a bachelor's degree in NS&E—less than half the rate of the majority white population.

Progress for underrepresented minorities in S&E graduate enrollment has been very modest. In 1975, they accounted for 3.7 percent of S&E graduate enrollment; by 1995, they accounted for 5.0 percent. Minority students are underrepresented in S&E graduate degrees. They earn 7 percent of the master's degrees in S&E fields and less than 5 percent of the doctoral degrees. Women in these minority groups earn the majority of these degrees. (See NSF 1996f for disaggregated degree data by sex within each racial/ethnic group.)

Figure 2-12.
Bachelor's degrees awarded in S&E, by sex



See appendix table 2-20.

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Americans, representing only 4 percent of the U.S. population, have considerably higher than average participation rates: almost 40 percent obtained a bachelor's degree, and over 12 percent earned such a degree in NS&E.

Recent participation rates do show some progress toward more diversity in higher education in general and in S&E fields, compared with 1980 and 1990 data. (See text table 2-5.) Low participation rates for blacks and Hispanics changed little throughout the 1980s, although they improved considerably in the 1990s, particularly in the social sciences. In 1995, 3.8 percent of the U.S. female population earned an NS&E degree, compared to 2.1 percent in 1980.

U.S. Students Studying Abroad

A recent study highlights the core elements of an international education that will be important for American youth preparing to work in the global economy of the 21st century (IIE 1997). Referred to as "transnational competence," this education involves a combination of cultural and technical skills, including:

- knowledge of commercial, technical, and cultural developments in a variety of locales;
- understanding of local customs and negotiating strategies;
- facility with English and at least one other major language;
- facility with computers; and
- skills in technology and awareness of their different cultural contexts.

The United States has traditionally been weak in providing foreign language instruction. More recently, however, universities are improving undergraduate education by attempting to provide meaningful international experience as an integral part of coursework. (See "International Engineering Programs in the United States.") While there are no national data on the short-term visits conducted under such enhanced undergraduate curricula, the number of courses taken for credit overseas have increased, including engineering courses. (See text table 2-6.)

Graduate S&E Students and Degrees in the United States

Trends in Graduate Enrollment

Enrollment in U.S. graduate S&E programs grew for almost 20 years, reached a peak of almost 440,000 students in 1993, and then began to shrink. From 1975 to 1993, the total number of students in graduate programs increased steadily

Text table 2-5.
Percentage of 24-year-olds earning first university degrees in S&E, by sex and race/ethnicity

Sex and race/ethnicity	Total 24-year-old population	Total first university degrees	Natural science degrees	Social science degrees	Engineering degrees	With first university degree	With NS&E degree	With social science degree
1980								
Total	4,263,800	940,251	110,253	138,682	58,810	22.1	4.0	3.2
Male	2,072,207	477,750	71,346	67,009	52,858	23.1	6.0	3.2
Female	2,191,593	462,501	38,305	68,623	5,952	21.1	2.1	3.1
White	3,457,800	807,509	100,704	151,839	60,856	23.4	4.7	4.4
Asian	64,000	48,908	3,467	3,039	3,866	29.5	10.2	4.8
Black	545,000	60,779	4,032	16,388	2,449	11.1	1.4	3.0
Hispanic	317,200	30,167	3,646	7,641	1,820	10.5	1.7	2.4
Native American	29,800	3,693	337	898	195	12.1	1.8	3.0
1995								
Total	3,576,400	1,062,151	123,647	207,032	63,330	32.8	5.4	5.8
Male	1,817,400	495,867	66,540	76,256	52,421	29.2	6.9	4.2
Female	1,759,000	566,284	55,925	108,056	10,850	36.6	3.8	6.2
White	2,863,400	856,686	84,675	156,472	43,726	31.2	4.8	5.5
Asian	148,600	30,027	12,007	10,336	6,785	39.9	12.7	7.0
Black	527,600	59,301	8,021	16,662	2,845	16.2	2.1	3.2
Hispanic	466,800	43,894	6,119	12,420	3,651	14.2	2.1	2.7
Native American	37,000	4,212	676	1,230	221	17.4	2.4	3.3

NS&E = natural sciences and engineering

NOTE: Population data are for U.S. residents only and exclude members of the armed forces living abroad.

SOURCE: U.S. Bureau of the Census, Current Population Reports, series P-25, Nos. 519 and 917 (Washington, DC)

See appendix tables 2-20 and 2-21. *Science & Engineering Indicators – 1998*

Text table 2-6.
U.S. students studying abroad, by field of study

	Total students studying abroad	Percentage studying					
		All S&E fields	Physical sciences	Math & computer sciences	Agriculture	Engineering	Social sciences & humanities
1987/88	62,341	19.9	2.5	1.2	0.8	1.4	14.0
1989/90	70,727	22.8	3.7	0.8	0.4	1.3	16.6
1993/94	76,302	46.7	5.3	1.1	0.9	2.3	37.1
1994/95	84,403	47.5	6.8	1.2	0.7	2.2	36.6

SOURCE: Institute of International Education, *Open Doors, 1995-1996: Report on International Education Exchange* (New York: 1996).

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at an average annual rate of 2 percent. Subsequent declining enrollment has averaged 1 percent annually. Fewer students enrolling in engineering, mathematics, and the computer sciences account for most of this decline. Engineering, mathematics, and computer science enrollment grew at a rate of almost 4 percent annually from 1975 to 1992, but declined 3 percent annually from 1992 to 1995. While a slightly increasing number of students continues to enroll in the social and natural sciences, the annual rate of increase in these fields slowed after 1992. Trends differ when examining subfields: a look at the natural sciences shows that graduate enrollment in the physical sciences has decreased, while enrollment in the biological sciences has increased (NSF 1996e).

Enrollment by Sex, Race/Ethnicity, and Citizenship

While there are fewer graduate students in science and engineering, U.S. students today are a more diverse group than in the past. In 1977, women represented only one-quarter of S&E graduate enrollment; by 1995, they accounted for 38 percent of enrollment. (See figure 2-13.) While women and minorities continued a decade-long trend of increased enrollment in graduate S&E programs in 1993, enrollment figures for foreign students and U.S. white males began a downward trend. (See figure 2-14.)

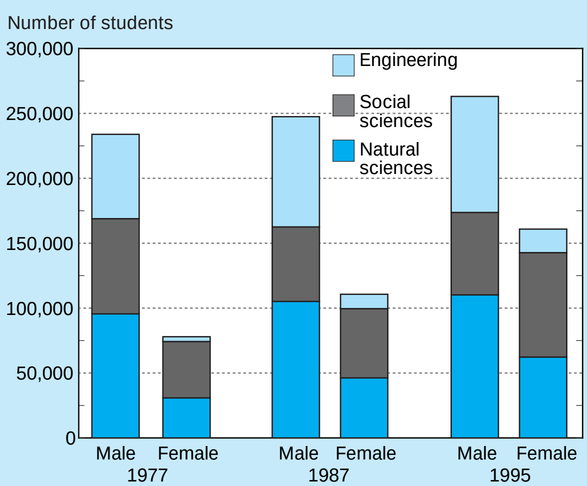
In 1992, foreign graduate students reversed their decade-long trend of increased S&E enrollment in U.S. institutions.

International Engineering Programs in the United States

International engineering programs (IEPs) allow U.S. students to gain valuable experience in an international setting. Traditional engineering curricula have been too tight and structured to allow engineering students to study abroad. IEPs, however, are customized to permit such study. A University of Cincinnati survey of universities with IEPs listed on the World Wide Web shows study abroad and work abroad components integrated into the engineering programs of about 25 major U.S. universities. A well-structured IEP gives students an opportunity to examine engineering in a foreign culture.

To promote the creation of IEPs, several universities in the United States and abroad are affiliated with the International Engineering Consortium. The consortium conducts a broad range of university-industry cooperative programs and continuing education programs. Members of academia and industry meet to discuss leading-edge technology, issues vital to the information age, and the nature of today's global marketplace. (For more information, see <<http://www.iec.org>>.)

Figure 2-13.
Graduate enrollment in S&E, by sex



NOTE: Natural sciences here include mathematics and computer sciences.

See appendix table 2-24. *Science & Engineering Indicators – 1998*

They decreased their enrollment each year since then. From 1983 to 1992, the number of foreign graduate students increased over 5 percent annually. From 1992 to 1995, their numbers decreased more than 3 percent annually. (See appendix table 2-25.)

The field of engineering illustrates both decreasing enrollment and increasing diversity. The number of students enrolled in graduate programs in engineering declined from approximately 118,000 in 1992 to less than 108,000 in 1995. But 1995 enrollment included almost 1,000 more women and 1,000 more underrepresented minorities than in 1992. One factor in the increasing enrollment of minorities in graduate S&E programs may be changing demographics—the higher growth rate in the minority population relative to the white population. The approximately 10,000-person decrease in engineering students from 1992 to 1995 was primarily due to declining numbers of foreign students and U.S. white males. In 1995, the number of foreign students represented about one-third of U.S. graduate enrollment in engineering, down from a peak of 34 percent in 1992. (See figure 2-15 for the declining enrollment of foreign students in graduate engineering.)

The recent decline in foreign students is likely influenced by the increasing educational opportunities in other countries. The growing capacity for S&E graduate education in Asian countries is shown not only in the expansion of higher education institutions in Asia (see "Growth in Institutions of Higher Education in Asia"), but also in the high rate of growth in earned doctoral degrees within Asian universities. (See appendix table 2-26.)

Foreign Students in All Levels of U.S. Higher Education

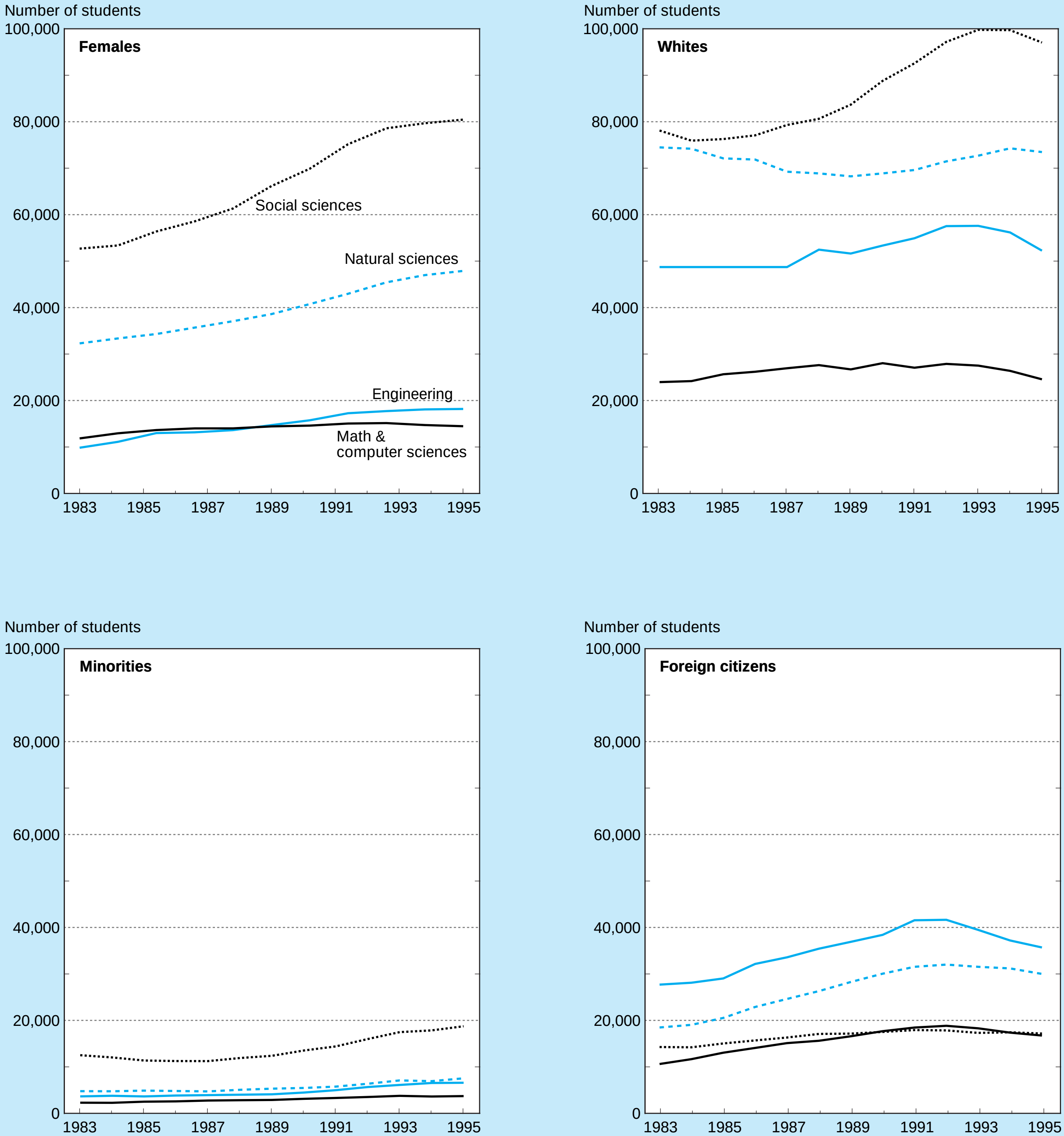
The majority of foreign students in the United States come from a small group of countries. Twelve leading countries of origin account for over 60 percent of the approximately 450,000 foreign students enrolled in U.S. higher education. Students from Asian countries—the most significant region of origin of foreign students in U.S. institutions—come to study at both the graduate and undergraduate levels. (See text table 2-7.) Students from China and India come to study mainly at the graduate level and overwhelmingly in NS&E fields. In contrast, students from Japan enroll mainly at the undergraduate level for non-S&E fields such as business administration. Enrollments of students from South Korea and Taiwan are more equally divided among graduate and undergraduate programs. Undergraduate students from South Korea and Taiwan in U.S. institutions study mainly non-S&E fields, while the majority of South Korean and Taiwanese graduate students enter S&E fields. (See appendix table 2-34.)

Master's Degrees

Over the past two decades, the overall trends in science and engineering degrees at the master's level show an increase in the number of earned degrees throughout the 1980s, with even stronger growth in the 1990s. The recent growth is mainly accounted for by the rising numbers of earned degrees in the social sciences and engineering, with relatively stable numbers in the natural sciences, mathematics, and computer sciences.

Examining trends within each field highlights the variations among different time periods of the past 20 years. In natural science fields, after a slight downward trend in the

Figure 2-14.
Graduate S&E enrollment for selected groups



NOTES: Data for women are available for odd years only before 1988. Minority data are for groups underrepresented in S&E: blacks, Hispanics, and Native Americans.

See appendix tables 2-24 and 2-25.

Science & Engineering Indicators – 1998

Text table 2-7.
Foreign student enrollment in U.S. higher education, by region of origin: 1995/96

Total, all regions	453,635
Africa	20,844
Asia	259,893
Europe	67,358
Latin America	47,253
Middle East	30,563
North America	23,644
Oceania	4,202

SOURCE: Institute of International Education, *Open Doors 1995-96: Report on International Educational Exchange* (New York: 1996).

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Text table 2-8.
Percentage of S&E master's degrees earned by minorities and foreign citizens

Race/ethnicity and citizenship	Natural sciences	Social sciences	Engineering
1977			
Asian	2.6	1.7	4.5
Black	2.4	6.2	1.5
Hispanic	1.5	3.0	1.6
Native American	0.3	0.3	0.1
Foreign citizen	15.6	7.0	21.8
1995			
Asian	7.8	2.7	9.0
Black	3.0	5.9	2.3
Hispanic	2.3	4.0	2.5
Native American	0.3	0.6	0.2
Foreign citizen	28.5	10.8	33.9

NOTE: Natural sciences here include math and computer sciences.

See appendix table 2-28. *Science & Engineering Indicators – 1998*

1980s, the number of graduate students successfully completing master's degrees increased in the 1990s. In mathematics and the computer sciences, the very strong growth rate in earned master's degrees in the 1980s (almost 8 percent annually) shifted to a more modest growth rate in the 1990s, about 2 percent. The slight downward trend in earned master's degrees in the social sciences turned around in 1989, with sharply increasing numbers of social science degrees since then. The rapid growth in engineering master's degrees after 1980 leveled off in 1989-91, increased from 1991 to 1994, and then again leveled off in 1994-95. (See appendix table 2-27.)

Master's Degrees by Sex

Over the 20-year period 1975 to 1995, males accounted for the strong growth in master's degrees in engineering, mathematics, and the computer sciences. Females were primarily responsible for the strong growth in social sciences; they also obtained a larger share of degrees in the natural sciences. However, the proportion of master's degrees earned by females increased considerably in the last two decades—not only in the natural sciences, but in engineering as well. In 1975, females earned 21.1 percent of the natural science degrees at the master's level and 2.5 percent of the engineering degrees. By 1995, females accounted for 41.0 percent of natural science degrees and 16.2 percent of engineering degrees. (See appendix table 2-27.)

Master's Degrees by Race/Ethnicity

In the 1990s, minority groups in the United States earned, in most cases, increasing numbers as well as increasing shares of master's degrees in S&E fields. The number of S&E degrees earned by Asian Americans consistently increased, especially in engineering, mathematics, and the computer sciences. The number of S&E master's degrees obtained by blacks grew modestly in most fields, with strong growth in the social sciences. Despite gains in individual S&E fields, the overall share of master's degrees in S&E earned by black students declined slightly from 1977 to 1995. Hispanics earned a modestly increasing number—and proportion—of degrees in the social sciences, as well as in engineering. White students showed modest growth in NS&E degrees earned in the 1990s, and strong growth in social science. Notwithstanding these gains, the share of master's degrees earned by white students in all fields declined during the 1977-95 period. (See text table 2-8 and appendix table 2-28.)

Master's Degrees by Citizenship

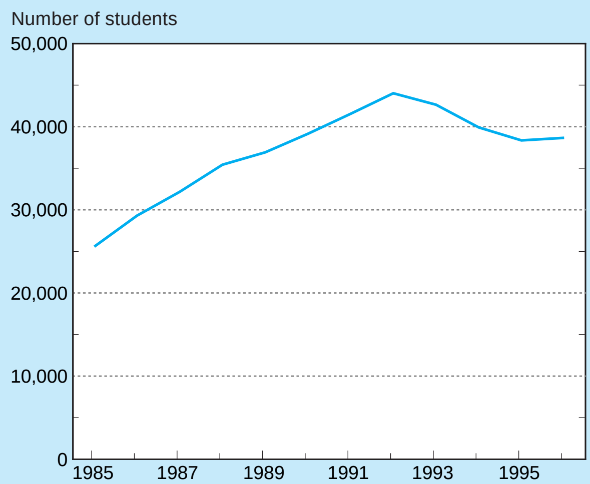
Analysis of master's degrees by citizenship shows a continuation of the trend toward a larger proportion of degrees going to foreign students in engineering, mathematics, and the computer sciences. In 1975, foreign students earned 21.8 percent of the engineering degrees and 11.3 percent of the math and computer science degrees. By 1995, foreign representation at the master's level was 33.9 percent in engineering and 34.7 percent in math and computer sciences. (See appendix table 2-28.)

However, the rate of growth of overall S&E master's degrees obtained by foreign students slowed somewhat in the 1993-95 period, primarily because of the leveling off in their earned degrees in mathematics and computer sciences. There is as yet no evidence of declining numbers of engineering degrees awarded to foreign students, even though foreign graduate enrollment in engineering decreased from 1993 to 1995 and leveled off in 1996. (See figure 2-15.)

Doctoral Degrees

From 1975 to 1985, the number of S&E doctoral degrees granted in the United States was relatively stable. After 1985, however, the number of such degrees grew, reaching over 26,000 by 1995. (See figure 2-16.) Large increases in the number of earned degrees occurred mainly in engineering, mathematics, and computer sciences. The number of degrees in these fields nearly doubled from 1985 to 1995. Natural science fields—

Figure 2-15.
Foreign student enrollment in graduate engineering programs



See appendix table 2-29. *Science & Engineering Indicators – 1998*

particularly the biological sciences—also contributed to the rising number of degrees, with a 30 percent increase.

Doctoral Degrees by Sex

Male doctoral degree recipients accounted for much of the growth in engineering, mathematics, and computer sciences, while female doctoral recipients were largely responsible for the increasing number of natural science degrees.

Within the past two decades, the share of S&E doctoral degrees earned by women doubled from 15.6 percent in 1975 to 31.2 percent in 1995. The proportion has differed by field. By 1995, females earned almost half of the doctoral degrees in the social sciences and 38 percent in the biological sciences. (See appendix table 2-30.) Growth in the proportion of degrees awarded to women was greatest in engineering subfields. By 1995, women earned almost 12 percent of all engineering doctorates, and 15 to 16 percent of doctoral degrees in chemical and materials engineering.

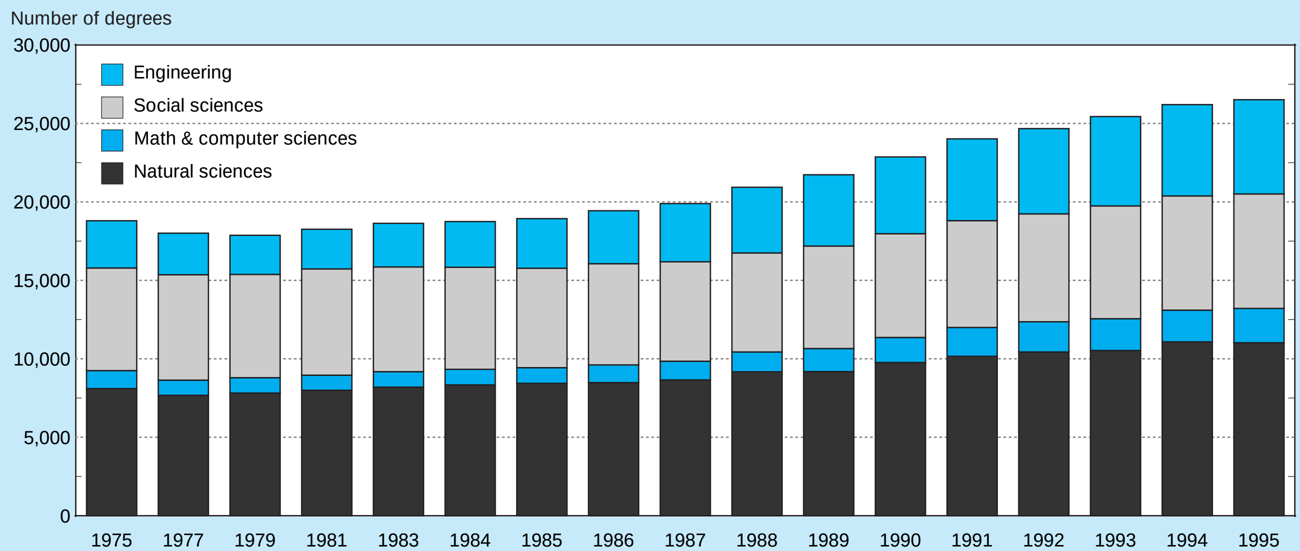
Doctoral Degrees by Race/Ethnicity

Underrepresented minorities within U.S. universities received almost 5 percent of all S&E doctorates awarded in 1995, up slightly from 3 percent in 1977. As a group, these minorities accounted for 8 percent of earned degrees in the social sciences, 4 percent in the natural sciences, 3 percent in engineering, and 2 percent in mathematics and the computer sciences. For black Ph.D. recipients, the largest numerical increases in the past decade have been in the biological and social sciences. The largest percentage increases have been in the biological sciences and engineering. (See appendix table 2-31 and NSF 1996d.)

Foreign Doctoral Students in the United States

In the past decade, foreign students have accounted for the large growth in S&E doctoral awards in U.S. universities. The number of foreign doctoral recipients in U.S. universities doubled in S&E fields from over 5,000 in 1986 to over 10,000 in 1995. This doubling translates to an 8.2 percent average annual increase. In contrast, the rate of increase in doctoral de-

Figure 2-16.
S&E doctoral degrees awarded by U.S. universities



NOTE: Doctoral degree data are available for odd years only before 1984.

See appendix table 2-30. *Science & Engineering Indicators – 1998*

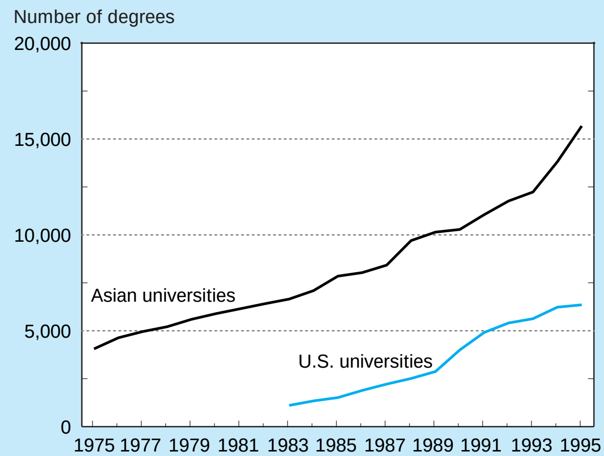
grees to U.S. citizens averaged only 1.9 percent annually.

Within NS&E fields, the proportion of doctoral degrees earned in U.S. universities by foreign citizens climbed from 31 percent in 1986 to 47 percent in 1994; it has since begun to level off. (See figure 2-17.) Foreign students from China, India, South Korea, and Taiwan have played a central role in this growth. In 1995, foreign doctoral recipients from these four Asian economies accounted for 59 percent of all S&E doctorates earned by foreign students (NSF 1996d). In 1995, the share of NS&E degrees earned by foreign students decreased slightly to 46 percent, mainly due to a decline in doctoral degrees earned by South Korean and Taiwanese students. Both of these economies (which are major contributors of foreign graduate students in the United States) have increased their internal capacity for graduate education in science and engineering, evidenced by the increasing number of in-country doctoral degrees in these fields. (See appendix table 2-36.)

Even as Asian students entered U.S. graduate programs in record numbers, Asian universities were expanding their own doctoral degree programs in S&E fields. In fact, the two phenomena are related. The desire to increase their within-country capacity to educate their students through the doctoral level required sending students abroad as a way of preparing more S&E faculty for expanded graduate programs within Asian universities. In the period 1988-94, the Asian effort to receive doctoral training in U.S. universities was particularly intense, as evidenced by an increase from 2,872 earned degrees in 1989 to 6,229 in 1994. The annual rate of growth in earned S&E doctoral degrees during this period was over 17 percent. This rate of growth has slowed considerably in the last few years, however.

Students from Asian countries are becoming less dependent on U.S. universities for their doctoral training. After 1993, the annual rate of increase in the number of earned S&E doctoral degrees within Asian universities greatly exceeded the growth in degrees earned by Asian foreign students within U.S. universities. (See figure 2-18.) While Ph.D. production in S&E fields is growing at a faster rate in Asian countries than in the United States, it should be noted that the base is lower. In 1995, total doctoral degrees in S&E earned in six Asian countries numbered 15,700. In that same year, U.S. universities produced over 26,000 doctoral S&E degrees; over 6,000 of these degrees were earned by foreign students from Asia. (NSF 1996e). In 1995, the number of doctoral NS&E degrees earned from universities within four Asian economies exceeded the number of such degrees earned by Asian foreign students within U.S. universities. Only for Taiwan do U.S.-earned NS&E doctoral degrees outnumber those earned within Taiwanese universities. However, in engineering, China, India, and South Korea still obtain more doctoral degrees from U.S. universities than from their home country universities. (See text table 2-9.)

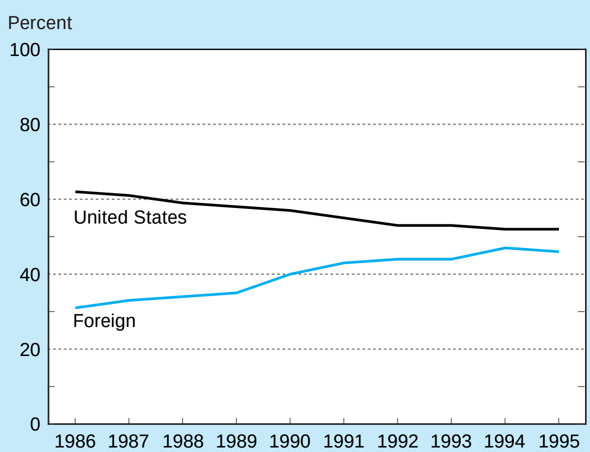
Figure 2-18.
S&E doctoral degrees awarded to Asian students by Asian and U.S. universities



NOTE: Data for U.S. universities are not available before 1983.

See appendix table 2-36. *Science & Engineering Indicators – 1998*

Figure 2-17.
NS&E doctoral degrees awarded by U.S. universities to U.S. and foreign citizens



NOTE: Foreign students include those on either temporary or permanent visas.

See appendix table 2-35. *Science & Engineering Indicators – 1998*

Besides providing doctoral training to foreign students from Asia, U.S. higher education is also linked to expansion of Asian capacity in S&E education through institution building. Leading research universities in the United States are advising developing countries in their design of higher education in science and engineering. For example, the Massachusetts Institute of Technology has accepted an agreement to create a scientific research university in Malaysia (Sales 1997).

Stay Rates of Foreign Doctoral Recipients in the United States

Until 1992, around half of the foreign students who earned doctoral degrees in S&E in U.S. universities planned to locate in the United States after completing their degrees. A

Text table 2-9.
NS&E doctoral degrees awarded to Asian students by Asian and U.S. universities: 1995

Student place of origin	Within country Ph.D. in: Natural sciences	Within country Ph.D. in: Engineering	U.S. university Ph.D. in: Natural sciences	U.S. university Ph.D. in: Engineering
Five-country total	8,576	6,327	2,335	3,268
China	1,373	1,659	773	1,802
India	4,077	348	572	499
Japan	2,143	3,009	30	51
South Korea	750	938	344	414
Taiwan	233	373	616	502

NS&E = natural sciences and engineering

SOURCES: **China**—National Research Center for Science and Technology for Development, unpublished tabulations, 1996; **India**—Department of Science and Technology, *Research and Development Statistics 1994-95* (New Delhi: 1996); **Japan**—Monbusho, *Monbusho Survey of Education* (Tokyo: annual series); **South Korea**—Ministry of Education. *Statistical Yearbook of Education* (Seoul: 1996); **Taiwan**—*Educational Statistics of the Republic of China* (Taipei: 1996); **United States**—National Science Foundation, Science Resources Studies Division, *Selected Data on Science and Engineering Doctorate Awards: 1995,* NSF 96-303 (Arlington, VA: 1996).

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significantly smaller proportion (one-third) received firm offers to remain in the United States for academic or industrial employment. The proportion of foreign doctoral recipients who plan to locate in the United States and accept firm offers differs considerably by country and region. Students from Asian countries, who are the most numerous, are the most likely to stay in the United States. In contrast, of the less numerous students from North and South American countries, fewer plan to locate in the United States.

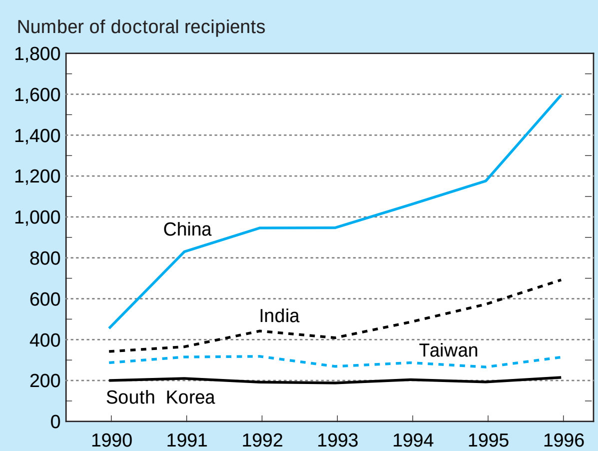
For the period 1992-96, the percentages of foreign S&E doctoral recipients planning to remain in the United States increased: over 68 percent planned to locate in the United States, and nearly 44 percent had firm offers to do so. This recent increase in stay rates, which may be temporary, is mainly accounted for by the sharp increase in the percentage of Chinese students with firm plans to stay in the United States. In 1990, 42 percent of over 1,000 Chinese S&E doctoral recipients in U.S. universities had firm plans to stay. By 1996, 57 percent of the nearly 3,000 Chinese S&E doctoral recipients from U.S. universities had firm plans to remain in the United States. The underlying cause for this shift is the large number of Chinese students granted permanent residence status in the United States in 1992 following China's response to student demonstrations. In 1996, students from selected countries in Europe also increased their stay rates after completing advanced S&E degrees from a U.S. university, but their numbers are small in comparison to Asian countries: 61 from the United Kingdom and 75 from Germany. (See appendix table 2-37.)

Among Asian countries, China and India apparently have a limited capacity to provide high-level employment to large numbers of returning recipients of doctoral degrees in science and engineering. In 1996, 57 and 59 percent, respectively, of the U.S. S&E doctoral recipients from these countries choose to accept employment in the United States. (See appendix table 2-37.) In contrast, only 24 percent of 1996 doctoral recipients from South Korea and 28 percent from Taiwan accepted employment offers in the United States. The trend in the 1990s has been for fewer doctoral recipients from these economies to remain in the United States because of within-country employment opportunities; this is particularly true of South Korean engineering doctoral recipients. (See figure 2-19.)

To a large extent, the definite plans of foreign S&E doctoral recipients to remain in the United States revolve around postdoctoral study rather than employment. Between 1988 and 1995, individuals from the five economies with the largest numbers of foreign doctoral recipients cited further study as their main reason to stay in the United States (58 percent), followed by employment in R&D (27 percent), teaching (7 percent) and other professional employment (8 percent). (See text table 2-10.)

A recent study of foreign doctoral recipients working and earning wages in the United States (Finn, 1997) shows that about 47 percent of the foreign students who earned S&E doctorates in 1990 and 1991 were working in the United States in 1995. The percentages are higher in physical sciences and engineering, and lower in the life sciences and social sciences. (See chapter 3, "Stay Rates of Foreign Recipients of U.S. Ph.Ds.") These stay rates differ more by country of origin than by discipline, however. The majority of the 1990-91 foreign S&E doctoral recipients from India (79 percent) and China (88 percent) were still working in the United States in

Figure 2-19.
Asian recipients of NS&E doctorates from U.S. universities with firm plans to stay in the United States



See appendix table 2-37. *Science & Engineering Indicators – 1998*

Text table 2-10.
Foreign recipients of S&E doctorates from U.S. universities with definite plans to remain in the United States: 1988-95

Place of origin	Total S&E doctoral recipients	Total definitely planning to remain	Primary activity			
			Post-doctoral study	R&D	Teaching	Other Professional
Canada	2,111	897	449	235	98	115
China	13,598	6,238	4,120	1,342	295	486
India	6,585	3,542	1,535	1,316	315	375
South Korea	7,872	1,765	1,324	266	121	55
Taiwan	8,778	2,411	1,197	863	145	208

SOURCE: National Science Foundation, Science Resources Studies Division, *Statistical Profile of Foreign Doctoral Recipients, by Major Country of Origin* (Arlington, VA: 1998, forthcoming).

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1995. In contrast, only 10 percent of South Koreans who completed engineering doctorates from U.S. universities in 1990-91 were working in the United States in 1995. (See appendix table 2-38.)

The same study looked at foreign doctoral recipients from 1970 to 1972. Finn estimated that 47 percent were working in the United States in 1995, and that the stay rate for that group had fluctuated around 50 percent during the 15 years leading up to 1995. There is no evidence of significant net return migration of these scientists and engineers after 10 or 20 years of work experience in the United States. This does not mean that there is no significant return migration; in fact, such migration is known to occur. (See "Reverse Flow of Scientists and Engineers to Asia" later in this chapter.) However, the fairly constant stay rates indicate that any tendency of the 1970-72 cohorts to leave the United States after gaining work experience here has been largely offset by others from the same cohorts returning to the United States after going abroad.

Postdoctoral Appointments[10]

Postdoctoral research positions in science and engineering in U.S. universities increased 5 percent annually from the mid-1980s, and continued this rate of growth until 1994. Most of the growth in the number of postdoctoral appointments, which reached almost 26,000 in 1994, can be accounted for by the expansion of research performed by universities and the concomitant increase in earned doctoral degrees. From 1985 to 1994, funding of research performed by U.S. universities increased at almost $1 billion a year in constant dollars, from a base of $10 billion. (See chapter 4.) However, in 1995 the rate of increase in the availability of postdoctoral appointments slowed considerably, dropping to only 1 percent. In that year, R&D expenditures for university-performed research also stabilized.

During the period of rapid growth in S&E postdoctoral appointments, foreign students earned an increasing proportion both of doctoral degrees and of subsequent postdoctoral appointments. From 1990 to 1994, U.S. universities provided slightly more than half of their postdoctoral appointments to non-U.S. citizens. During this period, the growth rate of domestic postdoctoral appointments was about 4 percent. However, like the recent decline of foreign graduate enrollments in science and engineering in U.S. universities since 1993, there has been a slightly smaller proportion of foreign postdoctoral appointments and a slightly increasing number of appointments to U.S. citizens, particularly in the sciences. Foreign postdoctoral recipients still receive the majority of such research positions within U.S. universities in engineering. (See appendix table 2-39 and chapter 3, "Postdoctorate Appointments.")

Mobility is a characteristic of postdoctoral researchers throughout the world, however. Foreign scientists and engineers represent approximately 50 percent of the postdoctoral pool in the United States; the United Kingdom and France have a high percentage of foreign postdoctorates as well, although the number of postdoctoral positions in these countries is much smaller. In addition, Japan is attempting to improve the quality of its basic research at universities by offering more postdoctoral fellowships for both Japanese and foreign doctoral scientists and engineers.

Foreign Faculty in U.S. Higher Education

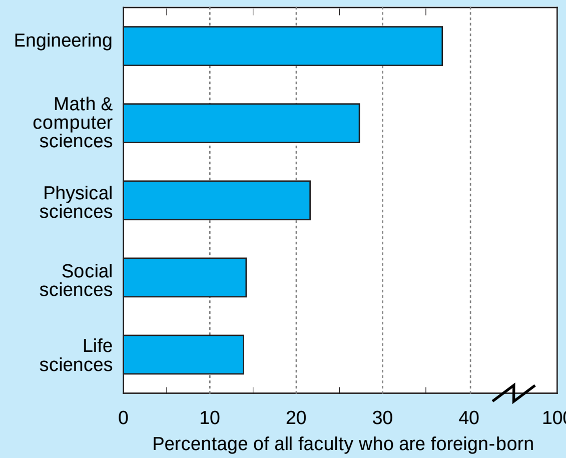
One indicator of mobility of S&E personnel in the world is the proportion of foreign-born faculty in U.S. higher education. The United States has been a magnet for trained scientists and engineers because of a well-developed economy able to absorb high-level personnel. (See chapter 3, "Foreign-Born Scientists and Engineers in the United States.") This section reviews data on those S&E faculty members in four-

[10] The data reported here are from the National Science Foundation's Survey of Graduate Students and Postdoctorates in Science and Engineering (NSF 1997b), and include university postdoctoral appointments only; these account for about 70 percent of U.S. postdoctoral appointments. The remaining 30 percent of such appointments are made by the National Institutes of Health, federal research laboratories, and private companies. Data on such appointments are not captured by this survey.

year colleges and universities who were born in another world region and whose primary job is teaching in an S&E field.[11]

The U.S. university system has been able to employ considerable numbers of foreign-born scientists and engineers. In 1993, foreign-born faculty in U.S. higher education represented 37 percent of the engineering professors and 27 percent of the mathematics and computer science teachers. (See figure 2-20.) These faculty are mainly from Asia and Europe, with the largest numbers coming from India, China, the United Kingdom, Taiwan, Canada, and South Korea. (See text table 2-11.)

Figure 2-20.
Foreign-born S&E faculty in U.S. higher education, by field: 1993



See appendix table 2-40. *Science & Engineering Indicators – 1998*

Reverse Flow of Scientists and Engineers to Asia

In the past decade, Asian foreign students—mainly from China, India, South Korea, and Taiwan—have earned nearly 45,000 doctoral degrees in S&E within U.S. universities. (See appendix table 2-43 and text table 2-12.) Compared to these major Asian countries of origin, the number of students from Singapore and Japan earning doctoral degrees in the United States is relatively small. Japanese industries often finance advanced training of their employees in U.S. universities for one to two years, but relatively few remain long enough to complete a doctoral program (NSF 1997c).

As mentioned above, a considerable number of doctoral recipients from Asian countries have received firm offers to remain in the United States. These Asian scientists and engineers have contributed significantly to the U.S. university system. In 1993, Asian-born faculty in U.S. higher education represented 19.7 percent of the faculty in engineering, 9.6 percent in the physical sciences, and 12.5 percent in mathematics and computer sciences. (See appendix table 2-40.) They have also contributed to U.S. industry as R&D personnel and by starting new companies. Immigrant scientists and engineers make up 28 percent of the S&E labor force in the United States (NSF 1995b). Many Asian scientists working in the United States participate in communication networks with home-country scientists. The dramatic growth in Asian economies has provided U.S.-based Asian scientists and engineers with more opportunities for cooperative research and consulting (Choi 1995).

The decision of foreign doctoral recipients to remain and work in the United States or to return home relates to job opportunities in their home country. Some dynamic Asian economies are gaining the capacity to absorb high-level S&E personnel. For example, foreign doctoral recipients from Taiwan, South Korea, and Hong Kong are successfully recruited to S&E positions within their home economies. In contrast, a high proportion of foreign doctoral recipients from India and China remains in the United States, since these countries currently have a limited capacity to offer high-level S&E employment to the 14,000 scientists and 7,500 engineers from these countries who have been educated in the United States in the last 10 years. (See appendix table 2-43.)

In the 1990s, Asian-born scientists and engineers working in the United States have begun a small reverse flow from West to East. Some are attracted by new or expanded research facilities based in their home countries; these facilities are often part of the country's strong investment in R&D infrastructure as a strategy to develop indigenous high technolo-

Text table 2-11.
Major countries of origin of foreign-born S&E faculty members in U.S. universities: 1993

Place of origin	Number	Percentage
Total S&E faculty	242,812	100.0
U.S.-born	193,606	79.7
Foreign-born[a]	49,206	20.3
S&E faculty from major countries of origin	23,762	9.8
India	5,696	2.3
China	4,263	1.8
United Kingdom	3,149	1.3
Taiwan	2,491	1.0
Canada	2,206	0.9
South Korea	2,163	0.9
Germany	1,604	0.7
Iran	1,369	0.6
Greece	821	0.3
Other	25,446	10.5

[a]This includes scientists and engineers whose first job is in S&E postsecondary teaching at four-year colleges and universities in the United States; it excludes scientists and engineers who may teach as a secondary job.

See appendix tables 2-40 and 2-42.

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[11]These data exclude S&E faculty members who teach in two-year and community colleges or who teach in an S&E field as a secondary job.

Text table 2-12.
S&E doctoral degrees awarded to Asian students by U.S. universities

Place of origin	Cumulative 1986-95
Total Asia	44,931
China	14,088
Hong Kong	952
India	7,554
Japan	1,276
South Korea	8,821
Taiwan	10,276
Thailand	956
Other Asia	1,008

See appendix table 2-43. *Science & Engineering Indicators – 1998*

gies. By 1992, the combined R&D investments of six Asian countries reached almost $100 billion in constant dollar terms, up from $35 billion in 1982 (NSF 1993).

Asian countries offer opportunities for high-level employment in science as well as expanding R&D budgets that can fund the majority of proposed research within these countries. Taiwan has been able to recruit senior scientists and engineers who had previously emigrated to the United States as students and young scientists. In the late 1980s, returnees with science degrees numbered between 500 and 1,000 per year. These scientists, including some Nobel prize winners, were hired in Taiwan as senior faculty for expanding graduate programs and as laboratory directors, particularly at centers of excellence such as the Synchrotron Center in Hsinchi Science Park. (see "Chinese Students Drawn Back to Asia," 1996). The increasingly large numbers of Taiwan returnees with science degrees—over 2,000 per year—are, since 1992, competing for fewer jobs; S&E positions in government and universities, except for the newly established East China University, have largely been filled with early returnees. The Taiwanese government is providing two-year postdoctoral appointments within high-technology industries to many recent returnees. These high-technology industries, however, are hiring permanently only in targeted areas in which there is a scarcity of trained S&E personnel, such as superconductivity, and solid-state industries.

Newly established Asian universities have successfully begun to recruit Western-educated scientists and engineers to expanding S&E departments. For example, the large majority of Chinese and South Korean professors in the Hong Kong University of Science and Technology (HKUST) and South Korea's Pohang University of Science and Technology received their doctoral training in the United States. In addition to the large portion of U.S.-educated faculty in the major universities of Hong Kong, former U.S. faculty are the deans and heads of almost all of S&E departments and make up a large majority of the directors of HKUST research institutes. (See text table 2-13.)

Similarly, the National University of Singapore and its attached five research centers and six independent institutes are recruiting senior scientists from the United States as deans, department heads, and laboratory directors. Many Chinese-born U.S. scientists have been attracted to Singapore's world-class facilities and equipment, high salaries, generous research funding, and opportunity to contribute to the development of the Asian region through science and technology.

International Comparisons of S&E Training in Higher Education

International Comparison of Foreign Students

For many countries within the Asian region, the attraction of students to S&E is an important aspect of their economic growth strategy, including expanding access and participation of foreign students. Universities in Australia are aggressively recruiting foreign students, and the government is including the provision of educational services to Pacific Rim countries as part of its national economic planning. The long-range plan is to have 2.8 million foreign students by 2010

Text table 2-13.
Leading scientists and engineers in Hong Kong universities, by country of Ph.D. award: 1996

University	Total	United States	United Kingdom	Canada	Australia	Hong Kong
Hong Kong University of Science and Technology						
Deans/department heads	15	14	0	1	0	0
Directors/research centers	16	12	3	1	0	0
Chinese University of Hong Kong						
Full professors	16	6	4	3	1	2
Directors/research centers	10	4	3	1	0	2

SOURCES: The Hong Kong University of Science and Technology, *Academic Calendar 1996-1997* (Kowloon, Hong Kong: 1996); and Chinese University of Hong Kong, *Calendar 1996-1997* (New Territories, Hong Kong: 1996).

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Text table 2-14.
U.S. students studying in Japan

	1995			1996		
Study level	Total U.S. students studying in Japan	With Japanese scholarship	Without Japanese scholarship	Total U.S. students studying in Japan	With Japanese scholarship	Without Japanese scholarship
Undergraduate	692	1	691	729	0	729
Graduate	255	127	128	271	137	134
Other	140	68	72	88	38	50

NOTE: For a description of Japanese exchange programs, see << http://www.twics.com/~nsftokyo/home.html>>.

SOURCE: National Science Foundation, Tokyo Office, unpublished tabulations (1997).

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Text table 2-15.
Foreign student enrollment in higher education in the United States and selected European countries

Country	Year	Total enrollment	Number of foreign students	Percentage of total enrollment
United States	1985/86	12,670,121	349,610	2.8
	1995/96	14,419,252	453,787	3.1
France[a]	1985/86	960,084	131,979	13.7
	1995/96	1,463,371	129,761	8.9
Germany	1985/86	1,550,211	79,354	5.1
	1993/94	1,875,099	116,474	6.2
United Kingdom ...	1985/86	1,032,491	53,694	5.2
	1992/93	1,528,389	95,594	6.3

[a]French data are for universities only and do not include engineering schools, business schools, and professional schools.

SOURCES: UNESCO, *Statistical Yearbook* (Paris: 1996)*;* Institute of International Education, *Open Doors 1995-1996: Report on International Education Exchange* (New York); and Ministère de l'Éducational Nationale, *Repères et Références Statistiques sur les Enseignements et la Formation* (Vanves, France: 1996).

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(Blight 1996). Japan currently educates 50,000 foreign students in its university system, mainly from China and South Korea. Through scholarships and fellowships, Japan seeks to double that number by the year 2000 (NSF 1997c). The number of U.S. students studying in Japan is growing, and includes many who have received Japanese scholarships. (See text table 2-14.) Taiwan, Singapore, Malaysia, and Hong Kong are replicating U.S. research universities and expanding their graduate S&E programs with Chinese students (Sales 1997).

Among European countries, foreign participation is attributable to a long-standing tradition of educating students from former colonies, as well as increased emphasis on European-wide exchanges. European countries have a higher percentage of foreign student enrollment than the United States when all levels of higher education are included. In 1995, foreign students accounted for between 6 and 9 percent of enrollment in higher education in selected European countries, compared to about 3 percent in the United States. (See text table 2-15.) Among European countries, universities in Germany and France—with minimal or no tuition required for higher education—are receiving an increasing number of Western and Central European students. Germany is attempting to build up the higher education institutions in the former East Germany and Central Europe. While the percentage of foreign students is relatively low, they are concentrated at the doctoral level in Europe and the United States.

International Comparison of Doctoral Training

Increasing global capacity in S&E education is evident at the advanced degree level. This section presents aspects of doctoral degree preparation among selected countries of Asia, Europe, and North America, including overall degree production and participation of women and foreign students.

Europe leads North America and Asia in number of earned S&E doctoral degrees. In 1995, doctoral degrees awarded in S&E fields by Western and Eastern European institutions totaled 45,647—about 60 percent higher than the North American level and almost three times as many as the number recorded for Asian countries. (See text table 2-16 and appendix table 2-32.)

Text table 2-16.
Doctoral S&E degrees awarded, by world region: 1995

Field	Three-region total	Asia	Europe	North America
Doctoral degrees, all fields	155,733	32,087	78,791	44,855
Science & engineering	89,818	15,678	45,647	28,493
Natural sciences ...	49,888	8,576	27,082	14,230
Social sciences	15,663	775	7,030	7,858
Engineering	24,267	6,327	11,535	6,405

NOTES: Natural sciences here include agricultural, mathematics and computer sciences. See appendix table 2-32 for countries included in each region.

See appendix table 2-32. *Science & Engineering Indicators – 1998*

Text table 2-17.
Share of doctoral S&E degrees earned by women in selected countries: 1995
(Percentages)

Field	United States	Germany	France[a]	United Kingdom	Japan[b]	South Korea	Taiwan
All S&E fields	31	22	NA	21	10	7	9
Natural sciences	32	26	35	34	11	13	17
Math & computer sciences	21	12	23	18	NA	13	13
Social sciences	50	34	45	33	25	10	23
Engineering	12	6	17	13	5	2	3

[a]In France, the natural sciences exclude the biological sciences, which are instead classified with health and medicine, and in which women earn 51 percent of the doctoral degrees. The social sciences include literature and the humanities.

[b]In Japan, mathematics and computer sciences are included in engineering. Percentages are based on university "coursework" doctoral degrees only, not those earned within industry.

SOURCES: **United States**—National Science Foundation, Science Resources Studies Division, *Selected Data on Science and Engineering Doctorate Awards 1995,* NSF 96-303 (Arlington, VA: 1996); **France**—Ministère de l'Éducation Nationale de l'Enseignement Supérieur et de la Recherche, *Rapport sur les Études Doctorales* (Paris: 1996); **Germany**—Statistisches Bundesamt Wiesbaden, *Prüfungen an Hochschulen* (Weisbaden: 1996); **United Kingdom**—Higher Education Statistics Agency, *Students in Higher Education Institutions, 1995/96* (Cheltenham: 1997); **Japan**—Monbusho, *Monbusho Survey of Education* (Tokyo: annual series); **South Korea**—Ministry of Education, *Stastistical Yearbook of Education* (Seoul: 1996); **Taiwan**—Ministry of Education, *Educational Statistics of the Republic of China* (Taipei: 1996).

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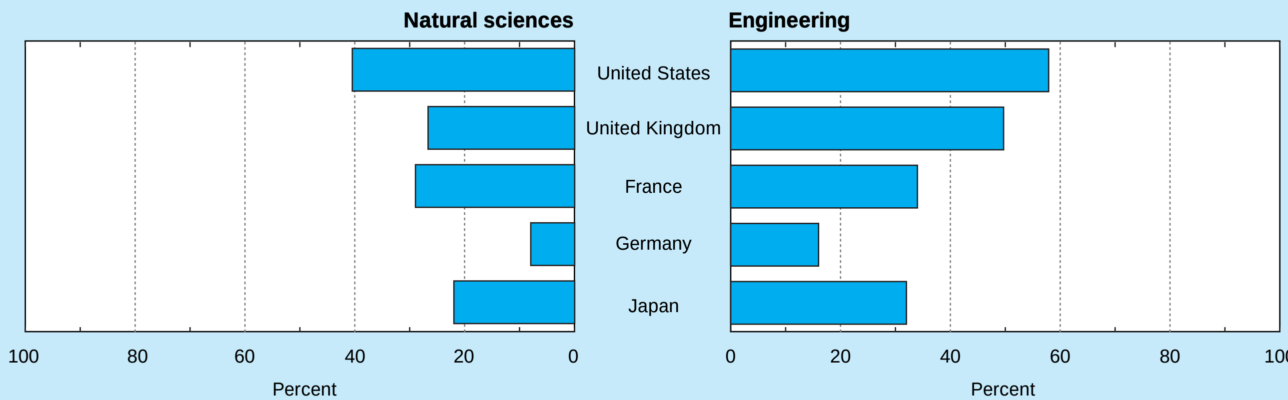
Figure 2-21.
Proportion of NS&E doctoral degrees earned by foreign students in selected countries: 1995 or most recent year



See appendix table 2-33.

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Comparing female representation in doctoral S&E degrees across countries, the United States ranks lower than France and higher than Germany. For example, within French universities in 1995, women earned a higher percentage of the NS&E doctoral degrees than did women in U.S. universities. (See text table 2-17.)

While graduate S&E programs are expanding rapidly in Asia, women have not yet entered those programs in large numbers. Women still earn only a small fraction of the doctoral S&E degrees issued in Asia. In fact, Asian women are more likely to obtain a doctoral degree in S&E fields from a U.S. university than from a home country university. For example, in 1995, women earned 7 percent of doctoral degrees in South Korea, but 12 percent of the doctoral degrees earned by South Koreans in the United States. For women from Taiwan, the figures were 9 and 16 percent, respectively (NSF 1996d).

The United States, the United Kingdom, and France are the world's leading countries in terms of foreign students in S&E at the doctoral level. For example, 57 percent of the engineering doctoral degrees awarded in the United States in 1995 went to foreign students. (See figure 2-21.) In that same year, almost 50 percent of the engineering doctoral degrees awarded in the United Kingdom, and almost 30 percent of those awarded by French universities in the natural sciences, were earned by foreign students.

Conclusion

Centers of S&E knowledge are multiplying around the world, particularly in Europe, Asia, and North America. The increasing global capacity in S&E education has implications for the United States as well as other nations. Higher participation rates in S&E degrees and a greater focus on S&E fields in higher education in other countries contribute to the potential pool of scientists and engineers. Such human capital is important for addressing complex societal needs and for technological innovations. In addition, the global expansion of S&E knowledge has the potential benefits of quickening the pace of development in other world regions. A larger global capacity for S&E education implies a U.S. need to stay competitive through continual improvement of its precollege and higher education system.

Decisionmakers throughout the U.S. higher education system have introduced improved curricula and teaching at the undergraduate level to broaden participation of all groups in science and engineering. Recent participation rates in S&E, disaggregated by race/ethnicity and sex, show some domestic progress compared to a decade ago; this reflects a somewhat more diverse U.S. student population pursuing higher education in science and engineering, particularly at the undergraduate level. In the 1990s, the number of white enrollments in undergraduate education leveled off and began to decline, while enrollment for all minority groups increased. Similarly, while overall undergraduate engineering enrollment has been declining, enrollment of women and minorities has been increasing, particularly in the 1990s. At the bachelor's level, the number of degrees earned by underrepresented minorities is increasing slightly in NS&E fields, and very rapidly in the social sciences. These trends bear watching as individual states introduce systemic reforms and other public policy changes for improved S&E curricula and teaching at all levels.

In graduate education, there has been some progress for women in S&E programs, and very slight progress for underrepresented minorities. At the master's level, women have made significant progress in earned degrees in the natural sciences, but minority groups showed only modest growth in these fields. At the doctoral level, the share of S&E degrees earned by women approximately doubled from 16 percent in 1975 to 31 percent in 1995. Minority students have slightly increased their proportion of doctoral S&E degrees to almost 5 percent in 1995, but they are still at low levels of degree attainment.

The enrollment of foreign S&E graduate students in U.S. universities reached a peak in 1992, and has since declined. The rate of growth in S&E master's degrees earned by foreign students has slowed in the 1990s due primarily to a decline in earned degrees in the computer sciences. However, declining graduate enrollment of foreign students in engineering has not yet resulted in a fall-off of the number of master's degrees in engineering earned by foreign students. At the doctoral level, the proportion of S&E degrees earned by foreign citizens reached 40 percent in 1994 before leveling off. The trend toward a somewhat lower concentration of foreign students in U.S. graduate programs is likely to continue, with fewer students from those places that are building their internal graduate S&E capacity, such as Taiwan and South Korea. The decline in foreign students from some Asian countries may be further exacerbated by the recent Asian economic crisis and the devaluation of currencies, making extended study abroad unaffordable.

The U.S. university system has accelerated the diffusion of S&E knowledge in the world through the education of foreign doctoral students, who have contributed both to the science and technology infrastructure in the United States and in their home countries. Many foreign doctoral recipients have remained in the United States for some time for further study or employment. As their home countries develop the need (and provide employment) for high-level skills, some of these foreign doctoral recipients return, bringing with them both their S&E education and U.S. work experience, further accelerating globalization of S&E. This improves other countries' economic competitiveness, as well as enhances the global good of improved scientific knowledge and world economic development. U.S. higher education is also enriched by the network of former doctoral students and faculty in key research centers in Asia and Europe. The benefits include enhanced cooperative research opportunities, expanded opportunities for U.S. graduate and undergraduate students to study abroad, and international postdoctoral research positions for young U.S. scientists and engineers.

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